ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CVIII.—No. 2804.] *LONDON: FRIDAY, SEPTEMBER 26, 1919.* [*Registered at the General Post Office as a Newspaper.*] [PRICE...9d. BY INLAND POST ... 11d.

Aveling & Porter, Ltd.,
ROCHESTER, KENT.
and 72, CANNON STREET, LONDON,
STEAM ROLLERS. ROAD LOCOMOTIVES.
STEAM CULTIVATING MACHINERY.
STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 7687

A. G. Mumford, Ltd.,
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See Advertisement, page 33.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

Henry Butcher & Co.,
VALUERS AND AUCTIONEERS
to the
ENGINEERING, FOUNDRY, & METAL TRADES.
ALSO FOR
PLANT AND MACHINERY. 6391
63 and 64, CHANCERY LANE, W.C. 2.

Cranes.—Electric, Steam,
HYDRAULIC and HAND.
of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 7304

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 7410
See Advertisement last week, page 140.

Plenty and Son,
LIMITED.
MARINE ENGINEERS, &c.
NEWBURY, ENGLAND. 9983

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 7260

A Time Recorder Wanted,
State price and where can be seen.—BOX T.R., SMITH'S Advertising Agency, Ltd., 100, Fleet Street, London, E.C. 4. W 484

Gas and Oil Engine Repairs.
—H. J. DAVIS & CO., Great Eastern Road, Stratford, E. 15.
Tel.: 736 and 737 Stratford.
Gram.: Rapidising, London. 1794

"Spencer-Hopwood" Patent Boilers.
Sole Makers:
W. H-SPENCER & CO., HITCHIN, HERTS.
See page 15. 7454

Invincible Gauge Glasses.
BUTTERWORTH BROS., Ltd.,
Newton Heath Glass Works,
Manchester. Od 9753

Electric Transporters.
S. H. HEYWOOD & CO., LTD., 7189
REDDISH.

Fuller, Horsey, Sons & Cassell,
SPECIALISTS
in the
SALE AND VALUATION
of
PLANT AND MACHINERY 1834
and
ENGINEERING WORKS.
11, BILLITER SQUARE, E.C. 3.

Iron and Steel
Tubes and Fittings.
9020
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 166, Sept. 19.

Yarrow & Co., Ltd.,
SHIPBUILDERS AND ENGINEERS,
GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia, 7769
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
Gear Cutting.
Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

Yachts, Launches, or Barges,
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3551
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO., 50, Wellington Street, Glasgow. 7898

Oil Fuel Appliances.
SYSTEMS { PRESSURE, AIR, STEAM.
FOR BOILERS OF ALL TYPES.
Kermodes Limited,
35, THE TEMPLE, DALE STREET, LIVERPOOL; and
109, FENCHURCH STREET, LONDON. 4076
NAVAL OUTFITS A SPECIALTY.

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds. Od 2487
See their Illus. Advertisement, page 151, last week.

Cochran Boilers.
MULTITUBULAR AND CROSS-TUBE TYPES.
See page 17. 7263

RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

Synonyms:—
"Aptol" Oils
AND 7184
Economy.
Henry Wells Oil Co.,
11, Haymarket, LONDON, S.W. 1.

Electric Lifts
(UP TO 35 TONS.) 7189
S. H. HEYWOOD & CO., LTD., REDDISH.

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.
London Office—14, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 7312

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, GLASGOW. Od 8547
Registered Offices: 108A, Cannon St., London, E.C.

John Bellamy, Limited,
MILLWALL, LONDON, E. 1216
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Tubes and Fittings.
Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 124. 7268

CO_2 Plants (CARBON DI-OXIDE)
for Chemical Wks., Mineral Water Mfrs., Breweries, and all other purposes. — AERATORS LTD., 159, Victoria St., S.W. 1 ("Pranspark, London.").

"Waterloo" Fire Extincteur
is the Engineer's machine. Compressed CO^2. Noscids Noalkalis. Instantaneous. Automatic.—BRITISH FIRE APPLIANCES Co., Ltd., 109, Victoria St., London, S.W.1

ON ADMIRALTY LIST.
John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C. 3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice Making Machinery.
Feed Water Heaters.
Feed Water Filters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c., &c. 7736

Cement.—Maxted & Knott,
LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest references. Established 1890.
Address, BURNETT AVENUE, HULL.
Cablegrams: "Energy, Hull." 6300

CHANTIERS & ATHLIERS
Augustin-Normand
67, rue de Perrey—LE HAVRE (France). 3800
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

MANUFACTURERS
Rubber
Valves and Packings
GUTTA PERCHA & RUBBER, LIMITED,
Toronto Canada. 7535

Electric Cranes.
7189
S. H. HEYWOOD & CO., LTD., REDDISH.

R. Y. Pickering & Co., Ltd.,
(ESTABLISHED 1864.)
BUILDERS of RAILWAY CARRIAGES & WAGONS.
MAKERS of WHEELS and AXLES of all kinds.
RAILWAY WAGONS FOR HIRE.
Chief Works and Offices:
WISHAW, near GLASGOW.
London Office:
3, VICTORIA STREET, WESTMINSTER, S.W. 3383

Wanted,
FOR MUNITIONS OF VICTORY,
SCRAP IRON, STEEL AND OTHER METALS
ALL CLASSES OF OBSOLETE PLANT.
WORKS, &c., for DISMANTLING.
JOHN JACKSON & CO., LTD., 7139
Balmoral Street, Scotstoun, GLASGOW.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM AND GAS KETTLES. } ROW'S PATENTS
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5739

Yarrow Patent Water-tube Boilers.
7169
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton.** 7889
See Full Page Advt., page 82, Sept. 19.

Forgings.
Walter Somers & Co., Ltd.,
HALESOWEN. 7110

"Delta" Brand HIGH-CLASS ENGINEERING ALLOYS.
Forgings, Castings, Bars, Sheets, Wire, Tubes.
THE DELTA METAL CO., LTD. 7166
E. GREENWICH, LONDON, S.E. 10 (& at Birmingham).

Taylor & Challen Presses.
8198
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, Sept. 19.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 7908

AUTOMATIC ANALYSIS OF FLUE GASES
Hays CO_2 Recorders,
Draught Gauges, Gas Analysers, Gas Collectors
Tested out on the High Seas in Naval Ships.
7054
L. C. HARVEY,
25, Victoria Street, Westminster, London, S.W. 1.
Telegrams— *Telephone*—
Fuelecon, Phone, London. 4980 Victoria.

Machine and Engineering
WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work, moderate charges.—HOSKER & RUSSELL, LTD., Queen's Wharf, Hammersmith.
NEW PATENT AUT.—HOSKER & RUSSELL, LTD., are prepared to undertake the manufacture of articles at present made abroad, and will be pleased to hear from firms desiring such work executed. 9211

Locomotive Traversers
(ELECTRIC). 7189
S. H. HEYWOOD & CO., LTD., REDDISH.

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND,
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C. 2.
See half-page Advert. last week and next week. 7526

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7940
See half-page Advertisement page 88, Sept. 5.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

Chief Engineer: C. E. STROMEYER, M.I.C.E.

Founded 1854 by SIR WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 7479

Northampton Polytechnic INSTITUTE,

280, St. John Street, London, E.C.1. Evening Technical Courses in all Branches of Mechanical and Electrical Engineering will COMMENCE on MONDAY, SEPTEMBER 22ND, 1919.

Full-time Sessional DAY COURSES in Engineering and in Technical Optics will commence on the 29th September, 1919.

The Laboratories, both Mechanical and Electrical, are well equipped with modern apparatus which, on the Mechanical side, provides for specialisation in Automobile and Aeronautical Engineering, and, on the Electrical side, for Specialisation in Alternate and Continuous Current Work, in Radio-Telegraphy and Telephony, and in Electrical Testing.

B. MULLINEUX WALMSLEY, B.Sc., Principal. A 344

UNIVERSITY OF LONDON.

King's College, Strand, W.C.

SESSION 1919-20.

FACULTY OF ENGINEERING.

SPECIAL ADVANCED LECTURES.

1—"The Preparation of Engineering Schemes and Contracts" (10 Lectures). Lieut.-Col. W. A. J. O'MEARA, C.M.G. Thursdays, at Six p.m., commencing October 9th, 1919.

N.B.—This course is intended to assist those preparing for the A.M.I.C.E. Exam, in "Drawings, Specifications and Quantities."

2—"Electrical Engineering with Reference to its Commercial Aspect" (four Lectures). By Mr. J. S. HIGHFIELD, Vice-Pres. Inst.E.E. Tuesdays, at Six p.m. (fortnightly), commencing October 14th, 1919.

3—"The Principles of Metrology and their Application to Engineering Standardisation" (three Lectures). By Mr. J. B. SEARS, Head of the Department of Metrology, National Physical Laboratory. Tuesdays, at Six p.m. (fortnightly), commencing October 21st, 1919.

For further particulars apply to the SECRETARY. A 586

MANCHESTER MUNICIPAL

College of Technology (UNIVERSITY OF MANCHESTER).

Principal: J. C. M. GARNETT, C.B.E., M.A. (late Fell. Trinity Coll., Cam.)

The Session 1919-1920 will open on 8th October. Matriculation and Entrance Examinations will be held in July and September.

DEGREE COURSES IN TECHNOLOGY.

The Prospectus gives particulars of the courses leading to the Manchester University degrees (B.Sc. Tech. and M.Sc. Tech.) in the Faculty of Technology, in the following Departments:—

MECHANICAL ENGINEERING (Prof. G. G. Stoney, F.R.S.).
ELECTRICAL ENGINEERING (Prof. Miles Walker, D.Sc.).
SANITARY and Municipal ENGINEERING.
THE CHEMICAL INDUSTRIES (Prof. F. L. Pyman, D.Sc.), including General Chemical Technology, Bleaching, Dyeing and Dyestuff Manufacture, Printing, Papermaking, Fermentation Industries, Metallurgy, Fuels.
TEXTILE INDUSTRIES (Prof. A. J. Turner, M.A., B.Sc.).
PHOTOGRAPHIC TECHNOLOGY.
ARCHITECTURE.
PRINTING.
MINING.

ADVANCED STUDY AND RESEARCH.

The College possesses extensive laboratories and workshops, equipped with full-sized modern apparatus, including machines specially constructed for demonstration and original research.

PROSPECTUSES of University Courses or of Part-time Courses sent free on application. A 115

Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Sec. "U" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7494 Offices of ENGINEERING.

Correspondence Tuition.—

B.Sc., Inst. C.E., Inst. M.E.; also Single Subjects by Honours B.Sc., A.M.I.C.E., etc. Fees moderate.—Address, 7679, Offices of ENGINEERING.

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 7882

Engineering Special Classes.

Marine & Aero-Engines, Alternating Currents, Wireless Course, Ferro-Concrete, Refrigeration, Pract. Maths. and Calculus.—PENNINGTONS, University Tutors, 364, Oxford Rd., Manchester.

Inst.C.E., Inst.Mech.E., and

all ENGINEERING EXAMS.—A Practical Engineer, A.M.I.C.E., &c. (recently demobilised), has now resumed coaching for above by CORRESPONDENCE, after 11 years' highly successful pre-war experience. Separate subjects may be taken. Excellent testimonials. Fees moderate.—Address, A 605, Offices of ENGINEERING.

TENDERS.

TO BUILDERS, CONTRACTORS, MANUFACTURERS AND OTHERS.

Re BRITISH CORRUGATIONS, LIMITED (in Liquidation).

Tenders are Invited for the

PURCHASE of the BRITISH PATENT, the FOREIGN and COLONIAL PATENTS, which have been granted for the principal countries of the world, and for the Machinery and Plant at the Company's Works, for the valuable process of manufacture of Corrugated Asbestos Cement Sheets. Certain of the Foreign and Colonial Patents are in force, but as regards others which have lapsed, the Liquidator is advised that applications for renewal will, in all probability, be favourably considered in view of the recent state of war.

Separate Tenders are also invited for the purchase of the Patents for British East Africa and the Transvaal, both of which are subject to application for reinstatement or renewal, as referred to above.

Payment for the whole of the above Patents and the Machinery and Plant must be made on completion. Subject to such arrangement as the Purchaser may be able to make with the Landlords of the Works, the Machinery and Plant must be removed therefrom within twenty-eight days from completion, and such removal will be at the risk of the Purchaser, who will also bear the cost thereof.

The Patent Deeds may be inspected at my office by appointment, but no Guarantee or Warranty is to be implied or given by me in respect of the above Patents or Machinery and Plant.

All Tenders should be received by me at my address, as below, not later than Nine a.m. on fourth day of October, 1919, but I reserve the right to refuse the highest or any Tender. All costs of Assignment to be paid by the Purchaser.

H. B. BARHAM,
Liquidator.

College Hill Chambers,
London, E.C. 4,
18th September, 1919. A 601

OLDHAM CORPORATION ELECTRICITY WORKS.

PLANT FOR SALE.

The Oldham Corporation Electricity Committee

Offer for Sale the following

PLANT:—

One WILLANS-SIEMENS 740 Kw. SET, compound wound shunt, 450-480 volts, compound 500-550 volts.

One 15-ton Electrically-driven 3-motor CRANE, about 38 ft. span.

The plant is in good working condition, and can be seen by appointment.

If necessary, arrangements could be made for the Corporation's staff to carry out the dismantling.

Full particulars can be obtained from Mr. F. L. OGDEN, Borough Electrical Engineer, Greenhill Electricity Offices, Oldham.

The highest or any tender not necessarily accepted.

J. J. WILLIAMS,
Town Clerk.

Town Hall, Oldham.
September 18th, 1919. A 553

PORT OF BRISTOL.

NEW COLD STORES, ROYAL EDWARD DOCK, AVONMOUTH.

TENDERS FOR LIFTS AND MUTTON HOISTS.

The Docks Committee are prepared to receive

Tenders for the Construction,

DELIVERY, ERECTION in place, TESTING and MAINTENANCE for six months after taking into use of SIX electrically-driven LIFTS and TWO electrically-driven MUTTON HOISTS at the New Cold Stores, Royal Edward Dock, Avonmouth, now in course of construction.

On and after Monday, the 29th inst., copies of Specification and Contract Drawings can be obtained from the undersigned on production of a receipt showing that a deposit of £5 has been paid to the Secretary of the Docks Committee, 19, Queen Sq., Bristol, to whom cheques must be made payable. The deposit of £5 will be returned to bona-fide tenderers after receipt of Tenders with all the prescribed documents and drawings.

Tenders must be enclosed in a sealed envelope, endorsed "Tender for Lifts and Mutton Hoists," and addressed to the Secretary of the Docks Committee, Docks Office, 19, Queen Square, Bristol, and must be delivered to him, accompanied by all the prescribed documents and drawings, before 10 a.m. Monday, the 20th October.

The Docks Committee do not bind themselves to accept the lowest or any Tender.

(Signed) THOMAS A. PEACE,
Engineer.

Engineer's Office,
Avonmouth Dock.
23rd September, 1919. A 638

METROPOLITAN BOROUGH OF WOOLWICH.

ELECTRICITY DEPARTMENT.

ALTERATIONS TO GLOBE LANE GENERATING STATION.

The Electricity Committee of the above Council invite

Tenders for the Supply, De-

LIVERY and ERECTION of approximately 50 TONS of CONSTRUCTIONAL STEEL WORKS.

Plans, with full details, can be inspected at the Electricity Dept., 44, Powis Street, Woolwich, after the 29th inst.

Tenders to be delivered, addressed to me, sealed and endorsed "Tender for Constructional Steel Works," at the Town Hall, Wellington Street, Woolwich, not later than 5 p.m. on the 7th October prox.

The Council do not bind themselves to accept the lowest or any Tender.

By order,
ARTHUR B. BRYCESON,
Town Clerk. A 659

APPOINTMENTS OPEN.

EAST HAM TECHNICAL COLLEGE.

EVENING CLASSES.

Principal: W. H. BARKER, B.Sc., F.C.S.

The Committee invite

Applications for the Post of

INSTRUCTOR of METAL WORK. Salary 16s. 6d. per evening of 2½ hours, on three evenings a week.—Forms of Application, which must be returned as soon as possible, can be obtained from the PRINCIPAL, Technical College, East Ham, E. 6.

F. R. THOMPSON,
Secretary.

Education Office,
Town Hall,
East Ham, E. 6,
24th September, 1919. A 640

A Large Firm of Engineers

in the Midlands have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4389, Offices of ENGINEERING.

UNIVERSITY OF MANCHESTER.

FACULTY OF SCIENCE.

The Council is about to Pro-

ceed to the APPOINTMENT of an ASSISTANT LECTURER in ENGINEERING. Stipend £250 to £300 per ann. according to qualification. Applications should be received not later than October 3rd, 1919.

For further particulars apply to the REGISTRAR. A 642

THE TECHNICAL COLLEGE, LOUGHBOROUGH.

H. SCHOFIELD, M.B.E., B.Sc. (Hons.), London, A.R.C.Sc. (London), Principal.

Wanted, at Once, Full Time

LECTURER in Automobile Engineering. Applicants should possess a University degree or its equivalent.

Salary £350, rising by increments of £25 per annum to £450.

Any further details, and forms of application, may be obtained from the Principal, to whom applications should be returned not later than October 14th, 1919. A 569

W. A. BROCKINGTON,
Director of Education.

CITY OF BIRMINGHAM EDUCATION COMMITTEE.

HANDSWORTH TECHNICAL SCHOOL.

Applications are Invited for

the POST of LECTURER in Engineering Subjects, Salary, £200 to £380. In addition to the salary indicated there is at the present time a War Allowance of £78 per annum.

The commencing salary will be dependent upon the experience of the applicant.—Full particulars may be obtained on application to the PRINCIPAL, Handsworth Technical School, Handsworth, Birmingham.

P. D. INNES,
Chief Education Officer. A 626

ENGINEERING & TRADE SCHOOL, LEYTON.

Applications are Invited for

the POST of INSTRUCTOR in Workshop Practice in the Junior Technical School. Candidates should have had recent experience in machine shop practice and will be expected to assist in some of the Laboratory Classes. Initial salary from £180 to £220 according to qualifications, &c.—For forms of application, which should be returned as soon as possible, send stamped addressed envelope to

R. DEMPSEY,
Clerk to the Governors.

Town Hall, Leyton. A 552

CITY AND GUILDS (ENGINEERING) COLLEGE.

The Delegacy of the College invite

Applications for the Post of

WORKSHOP INSTRUCTOR in Electrical Engineering, salary £160, with special bonus for the present at the rate of £100.

Applications, giving full particulars of age, training and experience, with testimonials or references should be addressed to Professor T. MATHER, F.R.S., CITY AND GUILDS (ENGINEERING) COLLEGE, Exhibition Road, London, S.W. 7, not later than 30th September. Ex-Service man preferred. A 540

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY.

Royal College of Science, London, S.W.

Vacancies for Two Demon-

STRATORS in the Department of Mathematics and Mechanics. Salary £200 (including bonus). Drawing office and workshop experience essential. Apply, by letter, in first instance, to PROFESSOR A. R. FORSYTH, F.R.S., Royal College of Science, London, S.W. 7. A 530

ENGINEERING & TRADE SCHOOL, LEYTON.

Applications are Invited for

the POST of TEACHER of Engineering Subjects in the Junior Technical School. Candidates should hold a University degree in Engineering or equivalent qualifications, and have had workshop and drawing office experience. Previous teaching and electrical laboratory experience desirable. Initial salary £190 to £240 rising to £350, according to qualifications.

Form of application may be obtained from R. DEMPSEY, Clerk to the Governors, Town Hall, Leyton, and should be returned as soon as possible. A 551

BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

DEPARTMENT OF MECHANICAL AND CIVIL ENGINEERING.

Applications are Invited for

the following Appointments:—

LECTURER IN MECHANICAL ENGINEERING.—Salary £300, rising to £400 by £15 annually. Engineering degree or equivalent qualification and drawing office or works experience essential.

ASSISTANT LECTURER AND DEMONSTRATOR IN MECHANICAL ENGINEERING.—Salary £150, rising to £350 in accordance with scale. Technical training, with degree of diploma, and drawing office or works experience essential.

ASSISTANT LECTURER IN ENGINEERING DRAWING AND DESIGN.—Commencing salary according to qualifications, but not less than £150, rising to £350 according to scale. Technical training, with degree or diploma, and drawing office or works experience essential.

A war bonus of £78 per annum is at present payable to holders of the above appointments.

Full particulars and form of application may be obtained from the PRINCIPAL of the College.

24th Sept., 1919. BY ORDER. A 481

KENT EDUCATION COMMITTEE.

ERITH TECHNICAL INSTITUTE.

Applications are Invited for

an ASSISTANT MASTER to teach Mathematics in the Day and Evening School. Initial salary £160 to £230 according to qualifications, together with an allowance for approved experience and training up to £115 (if the successful candidate is able to take charge of the teaching in mathematics throughout the School, an initial salary of £300 might be paid), rising by £15 per annum to a maximum of not less than £380 and not more than £420, in accordance with the Committee's scale.

Further particulars may be obtained from Mr. A. T. FLUX, Education Offices, Picardy, Belvedere, Kent. Letters of application, stating age, qualifications, training and experience, should be sent at once, to the Principal, MR. W. NEAGLE, Technical Institute, Erith Road, Belvedere, Kent.

E. SALTER DAVIES,
Director of Education.

13th September, 1919, A 426

Messrs. John Lysaght,

Limited, are REQUIRING the services of a GENERAL MANAGER for their Steel Works in Scunthorpe, Lincolnshire, the post being rendered vacant by the death of the gentleman who previously held this position. Applicants must have thorough knowledge of Coke Oven practice, Blast Furnace practice, especially in connection with the smelting of low grade ores, and the manufacture of Basic Open Hearth Steel, and all other duties appertaining to the management of a large Steel Works.—Applications, which will be treated in strict confidence, to be marked "Private" and addressed to JOHN LYSAGHT, LTD., Orb Iron Works, Newport, Mon. A 600

Manager for Engineering

Works in Calcutta WANTED, must have thorough experience in ship repairs and general engineering. Salary Rs. 1000 per month and commission.—Apply, stating age, experience and qualifications, to BOX M 723, LEE & NIGHTINGALE, Advt. Offices, Liverpool. A 477

Works Manager, Capable,

WANTED. Well up in repetition and general engineering work.—Full particulars and wages required to BOX No. 82, BROWN'S Advertising Offices, 166, Buchanan Street, Glasgow. A 543

Works Manager. — Gentle-

MAN REQUIRED to take charge of engineering works in the North. A free hand will be given to one able to understand men and get out large quantities of high-class repetition work.

When writing please state full experience, when free, and salary required. An interview will be arranged in London, and all communications treated in confidence.

Address, A 546, Offices of ENGINEERING.

Estimator Required for an

old-established engineering works in London; must be experienced in repetition work. Preference will be given to applicants having had drawing office or workshop experience. Reply (in confidence), giving full particulars of previous experience, age and salary required.—Address, A 597, Offices of ENGINEERING.

Applications are Invited for

POSITIONS in DRAWING OFFICE (London) of large Company engaged in the Petroleum Industry, from men with experience in either steam and power plant or general mechanical and structural engineering. Must be competent draughtsmen with some initiative. Commencing salary about £25 per month.—State age and experience to Z. F. 906, care of DEACON'S, Leadenhall Street, London, E.C. 3. A 646

Machine Shop Superintendent

WANTED for large machine shops, 700 machines. Must be a first-class man, and have held a similar position with up-to-date firm; medium and heavy work. State full particulars, age, present employ, salary, which will be treated in strict confidence.—Address, A 653, Offices of ENGINEERING.

Fitting and Erecting Shop

SUPERINTENDENT WANTED. Must be first-class man, with wide experience in control of large number of men and up-to-date factory experience. Marine experience an advantage but not absolutely necessary. State age, full particulars, present employ, salary, which will be treated in strict confidence. — Address, A 652, Offices of ENGINEERING.

Building Superintendent

REQUIRED for reinforced concrete construction in the East, for three years, with possible extension; salary £500 per annum, free passage. Candidates having wide experience of building generally, and particularly reinforced concrete construction, should apply at once by letter, stating age, full details of experience and earliest date prepared to sail.—To L., Box 606, T. B. Browne's Advertising Offices, 163, Queen Victoria Street, E.C. 4. A 598

Wanted, Chief of Inspection

Department; first-class man to be responsible to works manager; knowledge of testing of engines, on H and F brakes. Able to read all measuring instruments and drawings; not afraid of work.—State age, experience and salary required, to WORKS MANAGER, MARK WEBBER, Ltd., Guildford. A 568

Harbour Engineer, Holding

important public appointment, has a VACANCY for a YOUNG GENTLEMAN of good education as Premium Pupil.—Address, A 605, Offices of ENGINEERING.

Required, by Old Established

Engineering Company in India, CIVIL ENGINEER with up-to-date and expert knowledge of water works practice. Age under 30, and single.—Reply, giving full particulars of experience and salary required, to Z. R. 769, care of MESSRS. DEACON'S, Leadenhall Street, E.C. A 460

Heating Engineer, Required

by Glasgow Firm JUNIOR DRAUGHTSMAN with experience in estimating and to assist manager.—Address, stating age, experience and salary, A 449, Offices of ENGINEERING.

THE BRITISH ASSOCIATION.

(*Continued from page* 370).

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

UNDER the presidency of Professor A. Gray, of Glasgow University, Section A. discussed 25 communications on the four mornings, Tuesday, the 9th, to Friday, the 12th inst., between the hours 10 a.m. and 1.30 p.m., beginning fairly punctually as a rule and closing less punctually. The number 25 includes, and counts once only, the several discussions to which lengthy papers were contributed, and does not include a few committee reports. It thus sometimes required the firm ruling of the President to keep the speakers to time. The proceedings of the Section were undoubtedly of high interest, and the attendances very good throughout. Even the discussion of relativity attracted and retained to the end a very large number of members, though some of them were manifestly shocked by the heretical views expressed. on matters of such fundamental simplicity as the determination of length in space and time. The relativity problems are, and were at the meeting, interlinked with astronomical and ether problems, and thus further with spectroscopy, ionisation, the quantum theory, and general wave motion. Other important groups of communications dealt with were thermoionic valves and radiotelegraphy, and further geophysics and seismology.

The Presidential Address, a paper on viscosity at high pressures and temperatures, and some miscellaneous and purely mathematical papers stand more apart. We will, in our report on the proceedings, follow the general sequence as just indicated irrespective of the order in which the papers came on, and we will first, after the Presidential Address, notice the general discussion on relativity, though it was preceded by Professor Eddington's account of the observations which he conducted during the total solar eclipse of May 29 last for the purpose of deciding whether the propagation of light is affected by gravitation, as it should be according to Einstein's generalised principle of relativity. The measurements of the photographs then taken have not yet been completed, and Professor Eddington was hence not in a position to state whether or not he would confirm the theory.

We should here mention the sectional officers. Professor Gray was supported as President by the Vice-Presidents Colonel Sir Charles Close, R.E., and Professor A. N. Whitehead, Sc.D., F.R.S.; the Secretaries were Dr. W. Makover, M.A. (Recorder), of the Imperial College, South Kensington, Dr. H. R. Hassé, of Manchester University, Mr. J. Jackson, of Greenwich Observatory, Dr. A. O. Rankine, of University College, and Dr. E. Fenwick, of Bournemouth.

PRESIDENTIAL ADDRESS.

Professor A. Gray had not given his address a heading, but we may perhaps say that his theme was the organisation of physical science for the benefit of the country with general reference to the war, and that he dealt with it in a decidedly critical spirit. His general standpoint with respect to war and peace is indicated by the sentence: "I wish all success to the League of Nations, but we shall prove ourselves even greater fools than we have been in the past if we do not use all possible means to prepare ourselves against eventualities." Having paid his tribute to the memory of Carey Foster and Rayleigh, he turned to the part which physical science had played in the war. That part had not been as decisive as it might and ought to have been, and the lack of scientific organisation had not yet been brought home to our military chiefs. In 1915 he had proposed to the Royal Society that a central committee be established, representative of the centres of scientific teaching and work in pure and applied science, to nominate representatives at each centre, university or society, such as the Institution of Engineers and Shipbuilders of Scotland and of the North-East Coast of England; the central committee would then be able to obtain ready information as to men available for particular posts and to bring the schools of science and the workshops of the country into co-operation.

Two committees, he stated, had actually been appointed, but they had ceased to be called after a week or two. Officers had been wanting; but nominations to commissions had been left to the three leading London technical institutions which young engineers could hardly join before they had begun to earn some money. The formation of a general record of graduates for special service ought not to be difficult, he thought. Referring to his own experience on the Inventions Panel of the Ministry of Munitions, Professor Gray had something to say on the absurdity of many suggestions, such as sending up magnets or whole electromagnetic plants to bring down Zeppelins, or destroying hostile aircraft by some novel mysterious, but destructive agency. The residuum of valuable inventions had been referred to various departments, and there had been much delay owing partly to inertia and ignorance, whilst clumsy enemy contrivances had frequently been copied without hesitation. Some problems had suffered because the officers examining them had themselves been engaged in the solution of these very problems, which they regarded as their own special job; it was manifestly unfair to ask such officers to judge the work of outside inventors. A testing board should consist of well-qualified physicists and experts; the "open mind" was not worth having, but those carrying out the examination should not in any way be in the employment of the inventors, whether "outside" or "inside."

The services of university men, Professor Gray continued, had been grudgingly recognised by the authorities, who saw no good in officers who were not skilled leaders of men and had demobilised them again without the least regard to exceptional qualifications. Eminence in science was still a disqualification for any share in the conduct of the affairs of this great industrial country. Professor Gray had heard an eminent statesman, who was to be our minister or proconsul and the conservator of our national resources, suggest that an electric efficiency of 98 per cent. might, by the progress of science, be increased fourfold. Physicists in particular were hardly recognised unless they happened to be chemists, whilst many opticians on the "reserved occupations" list were merely traders. Professor Gray was glad that an Institute of Physics was being provided which, like the Institute of Chemistry, would secure recognition of research. But there was danger in the general centralisation now aimed at. A body sitting in London was to decide the subjects for research and the grants to be allocated; he would protest against handing over the awards of the Carnegie Trust for the Universities of Scotland to a London organisation, just as the great Universities of England would probably have something to say against the general administration of their special research scholarships. Moreover, the actual emphasis seemed to be on the promotion of industrial research. Pure science was the most important thing, and control of research in pure science would inevitably defeat itself; "beware of attempting to control or 'capture' the laboratories of pure science in the colleges of the country."

Passing to the teaching of physics, Professor Gray said that dynamics should be a physical subject, and only secondarily a mathematical one. The student should be able to handle rotating bodies, to test the laws of precession and nutation, and should learn to think in vectors without necessarily referring either to Hamilton or to Grassmann. Vector ideas were of the utmost importance, and Professor Gray, therefore, deprecated that the teaching was so much confined to rectilineal motion. The true meaning of a rate of change of a directed quantity, even of velocity and acceleration, was missed, as the following would explain:—A vector quantity of a certain direction and of magnitude L was turning in a plane with angular speed ω; this turning caused a rate of production of the vector quantity about a line in that plane, perpendicular to the former, of amount $L\omega$. Thus a particle moving in a curve with speed v had momentum mv forwards along the tangent at the position of the particle; the vector was turning towards the principal radius of curvature R at the point at the rate v/R; towards the centre of curvature momentum was hence growing up at a time rate mv^2/R. Dealt with in this way, with angular momentum instead of simple momentum, the motions of the principal axes of a rigid body gave the equations of Euler intuitively, and the mind-stupefying notions of centrifugal couples and the like were swept away. The want of appreciation of the principles of rotational dynamics, Professor Gray continued, was appalling. A gyrostat, as ordinarily considered, was a closed system; when we did away with the closedness, the dynamical theory was quite different. Two interlinked systems separately unstable, could be rendered stable, even in the presence of dissipative forces. When a certain product of terms was positive there was angular acceleration, not retardation, of the gyrostat frame; this acceleration was a means of supplying energy from without to the system, the energy necessary to preserve in operation the functions of the system. This important stabilising action of acceleration of the compound motion was lost sight of by those who criticised gyrostatic appliances from the usual erroneous point of view. Professor Gray also believed that it was by analogy a guide to the explanation of more complicated systems in the presence of energy-dissipating influences, and that the breaking down of stability or death of the system was due to the fact that energy could no longer be supplied from without in the manner prescribed for the system by its constitution.*

In his concluding remarks, Professor Gray drew attention to the importance of Rutherford's discovery† that the large range atoms arising from the collisions of α particles with nitrogen were not nitrogen atoms, but probably charged atoms of hydrogen or atoms of mass 2. It seemed that in order to break atoms down into some primordial constituents, it was only necessary to strike the more complex atoms with the proper kind of hammer.

In proposing and seconding the vote of thanks to the President, both Professor G. N. Whitehead and Sir Oliver Lodge, dwelt on Professor Gray's work in rotational dynamics, and expressed their general agreement with his outspoken criticisms and his plea for untrammelled university research.

THE PRINCIPLE OF RELATIVITY.

In introducing the general discussion on the Principle of Relativity, Professor A. S. Eddington, F.R.S., of the Cambridge Observatory, remarked that an investigation might advance science in two ways, by solving a problem or by formulating a problem. It was unsafe to dogmatise which of the two was of greater service to science; for the solution had often to be modified, whilst the discovery that a definite problem existed marked a permanent advance. The researches connected with the principle of relativity attempted both these advances. But Professor Eddington hardly knew whether he ought to attack or to defend the principle; for he could not yet say whether or not his eclipse observations would confirm Einstein's ingenious solution. If they should not, however, the problem would remain with us; we could not give a sigh of relief and go snugly back to the old ideas—or lack of ideas—of the nineteenth century. The problem formulated concerned the meaning of "length" or "distance" in space and in time. That meaning was fatally ambiguous. To take an example: According to Euclid two sides of a triangle were together greater than the third. The truth of that statement could not be settled by purely mathematical reasoning; the statement was true in some systems of geometry and false in others. Length measured by physical means seemed to support the law; by stretching the tape a little, however, one might disprove it. That would be cheating, of course, and physicists demanded all measurements to be made with rigid scales. "But what is a rigid scale? It is no good saying that it is a rod which never changes length—because the length has to be

* Professor Gray has kindly offered to supplement these very brief statements by some explanatory notes on an early occasion.

† See ENGINEERING, June 20 last, page 793. "Atomic Projectiles and Collisions."

measured by a rigid scale, and no scale, of course, however stretchable, would change length as measured by itself. You cannot use a rigid rod to define length and at the same time use length to define a rigid rod." He would define a rigid rod as free from certain recognised defects, of a perfect material, yet having properties common to all kinds of matter. But there was the Michelson-Morley experiment expected to show the change in the earth's motion through the ether, say between winter and summer. It unexpectedly gave null result. To account for this Fitzgerald had proposed that the whole apparatus changed dimensions according to its motion through the ether, and that explanation was rendered plausible by the researches of Larmor and of Lorentz showing that the electric forces which presumably maintain the shape of a solid body could be altered by the motion through the ether, so that the body could take up a new equilibrium position. That explanation was almost universally accepted, until relativity was proposed in 1905, and it was still held probably by those opposed to relativity. Nevertheless it was impossible because self-contradictory. The contraction was suggested as an innate property of matter; a rigid measuring rod should therefore possess that property, but such a rod could not alter length because length was the property measured by a rigid rod. We had to give up either FitzGerald's hypothesis, or the definition of length; to do the latter would undermine the interpretation of all physical experiment.

Professor Eddington could only indicate briefly the solution of the difficulty offered by the relativity theory. Length was still defined as the quantity measured by a rigid rod, but length was not a property of the object measured; it was a relation between the object and the observer. A rod might at the same time have all sorts of lengths corresponding to its relations to different observers. There appeared to be a contradiction in the Michelson-Morley experiments because two observers were mixed up in it; the one doing the actual experiment was travelling with the earth in its orbit; the other who worked out the theory remained at rest in space. There was a contradiction because the length relation was different for them. To the calculator the length of the rod was a relation of the rod to himself and had nothing to do with the rod of the practical experiments.

The value of a length was somewhat like the value of a *l.* note; estimated in terms of *l.* notes, the value never altered, estimated in other commodities the values might be said to diminish; it all depended upon the observer. Now Minkowski discovered that, though length of space and length of time were not absolute, but dependent upon the observer, there was an absolute quantity, called the interval between two events made up partly of space and partly of time; hence that curious interdependence of space and time so characteristic of the relativity theory. Most people found it harder to realise that time was not absolute than that length was not absolute; but the time we felt was not the absolute flow of time. The outburst of Nova Aquilæ (the parallax of the star was unknown) might be dated back to 1600, but we could not say absolutely that it took place before the war; and to a man travelling through space at the velocity of light and returning to the Earth, a journey reckoned in years on the Earth would appear an instant.

Passing to the generalised theory of relativity (of 1915) Professor Eddington remarked that many people resented Einstein's introduction of a new law of gravitation. Why not stick to Newton? But we did not know what the Newtonian law of inverse squares of the distance was. The law was indefinite since distance depended upon the observer. They also objected that Einstein's law was very complicated, and Newton's simple. Newton's law was certainly expressed very shortly—so shortly that nobody could tell what it meant; by the time all the necessary definitions were given, Einstein's law which appeared complicated, because it explained its meaning of distance, mass, co-ordinates in precise terms, was the simpler. The old theory of 1905 explained the failure of the Michelson-Morley experiment of thirty years ago; the new theory of 1915 predicted the new effect of gravitation on light. It said that a ray of light passing the sun should be bent towards the sun, not owing to any action of the corona, but owing to the gravitational field. The wave-front should be bent inward, the velocity of light should be slower near the sun than further away from it, and the change should be proportional to $(1 - 2\Omega)$ (where Ω was the gravitational potential) or to $(1 - 2m/r)$. The trouble was that in speaking of equal and unequal velocities and times we seemed to fall into the old error. Professor Eddington, referring back to his definition of length, would define equal times as the intervals in which light travelled equal lengths. That implied that light always had the same velocity; but he had just asserted that it had not. In speaking of the inner end of the wave-front as slower than the outer, he had, he said, in fact not been quite correct. That statement was true if time and space were Euclidian, but they were not Euclidian in a gravitational field, though that was the most horrifying thing to non-relativists. The interval between two events in Euclidian space and time was given by $ds^2 = c^2dt^2 - dl^2$ (where c was the velocity of light); for non-Euclidian space and time by $ds^2 = c^2(1 - 2\Omega)\,dt^2 - (1 + 2\Omega)\,dl^2$; in these formulæ ds was the absolute thing, whilst dl and dt depended upon the observer. As regards the eclipse effect in question, the bending of a ray of light coming from a star near the Sun, there were two or three views. There might be no effect at all. Secondly, since the electric force on a charged body added to the inertia of the body an amount proportional to the electromagnetic energy of the field, and since light was a form of electromagnetic energy—possessing momentum—as we knew from the radiation pressure—a star seen just on the limb of the Sun should appear 0·87 second of arc away from it, the deflection being smaller for stars less close to the Sun. Thirdly, there was the Einstein effect of double the value just stated, namely, 1·75 seconds, this effect arising (as already explained) because the light velocity should be smaller in a gravitational field than in a vacuum. This retardation effect would in fact be somewhat analogous to the effect of the matter in the corona which would act like a lens, bending the ray towards the sun; that material effect would be too small, however, to vitiate the result. We have here interposed Professor Eddington's communication on the eclipse photographs which, as we have mentioned, was read before the general discussion.

PHOTOGRAPHS OF TOTAL ECLIPSE OF MAY 29, 1919.

The Joint Permanent Eclipse Commission, Professor Eddington said in exhibiting his photographs, had sent out two expeditions to determine whether light had weight, one consisting of Dr. Crommelin and Mr. Davidson, from Greenwich, to Brazil, and the other consisting of Mr. E. T. Cottingham and himself, to the rocky Portuguese island of Principe [in the Gulf of Guinea, a few degrees north of the Equator]. On this island, which was difficult of access, they had mounted their instruments about 500 ft. above sea-level. To characterise the magnitude of the effect looked for Professor Eddison remarked that a bullet passing the Earth at the velocity of light would, by the attraction of the Earth be deflected by 16 ft. in the first second, *i.e.*, the bullet would appear to fall through that small space; that effect was quite imperceptible, but a solar eclipse should as mentioned show an effect of about 1 second of arc, equivalent to the angle under which a three-penny piece would appear at a distance of a mile. The measurements would not be of unusual difficulty for astronomers, though eclipse problems were severe. The eclipse of last May ought to have been favourable, since totality lasted 5 minutes, and quite a number of stars were near the sun; but they had much been disturbed by clouds, 10 of the 15 plates obtained with exposures up to 3 seconds were practically failures, and on the other plates they could only measure five stars instead of the possible 15—with what results he could not yet say, as we explained already. The photographs spoiled by clouds showed, however, a most remarkable prominence, an arch rising to a height of over 100,000 miles, underneath which several smaller arches could be distinguished. That prominence was also observed in Brazil and at Cambridge, in the latter place for 36 hours. Dr. Stratton remarked during the discussion of the communication that the prominence had at Cambridge first looked like the cloud of smoke rising from a chimney which descending had reached the Sun again near the solar equator. Some further comments by other speakers on the eclipse photographs will presently be mentioned.

We now return to the general discussion on relativity which was resumed by Dr. L. Silberstein, late professor in Rome, who came to London some years ago. Sir Oliver Lodge, he said, had hoped that the effect found as a result of the eclipse observations would be 0·87 second and would at any rate be distinct and decisive; Professor Gray had remarked that 0·87 would save trouble, but we might have to face 1·75. Dr. Silberstein himself hoped the result would be 0. He did not wish to attack Einstein's theory of 1905 which still yielded wonderful results, nor his relativity of 1915, but he opposed relativistic gravitation as barren. That gravitation theory was, apart from the invariants' principle, based upon Einstein's equivalence hypothesis, and had so far predicted three effects:—(1) A shift of the solar or stellar spectrum lines to the red, with respect to the terrestrial lines; (2) A bending of the light ray, as discussed by Eddington; (3) A secular motion of the perihelion of the planets (which could only be observed in the case of Mercury, being too small for the other planets). Going into the mathematics of the problem, Dr. Silberstein showed how the three effects followed from Einstein's special time element. But C. St. John (Mt. Wilson Observatory) had found effect (1) to be nil (the displacement would depend upon the differences in gravitational potential between the solar and terrestrial fields and should amount to about 0·01 Angström unit); hence Dr. Silberstein did not expect that any bending (2), and the Rev. A. L. Cortie had previously stated (we will quote him presently) that Campbell had not observed any bending during the eclipse of 1918. As regards effect (3), the motion of the perihelion of Mercury, that had already been accounted for by Seeliger and Newcome as due to a perturbation of Mercury's orbit by the zodiacal light, and when the two first effects had not been confirmed Dr. Silberstein had last year shown in the *Philosophical Magazine* that the equivalence hypothesis would raise the regress of the perihelion by 5½ seconds of arc to 48½ seconds. Dr. Harold Jeffreys had subsequently in the same journal expressed his concurrence with Silberstein's representation of these phenomena, because it involved only a small inclination of 8 deg. of the plane of the zodiacal light to the ecliptic Finally, Dr. Silberstein denied that a bending of 0·87 second was demanded by the electro-magnetic theory of light; in his opinion, therefore, none of the special effects discussed would have any existence.

Sir Oliver Lodge agreed on the whole with Silberstein, whom he followed in this discussion; he would leave space and time to mathematicians, correcting for changes in length as we corrected for changes in making absolute temperature measurements; but Professor Eddington considered the imperfections of a measuring rod and of a gas as quite different things, since the ideal gas had no molecules of finite size. The Rev. A. L. Cortie, S.J., of Stonyhurst College, to whom we have already referred, said that in taking his photographs during the total eclipse of June, 1918, W. W. Campbell had had 43 stars on his plates which showed no effect, though the effect should have been different for different stars; but Campbell had used a camera of small focal lengths, whilst a large focal length was desirable. Father Cortie was afraid, therefore, that Eddington's photographs, whatever the result, would not settle the matter. Professor F. A. Lindemann, of Oxford, submitted that the evidence of the shifting of the lines (effect 1) was of little value as long as we knew so little about the origin of spectra; the correction of measurements required in non-Euclidian space near a large body would be enormous. Mr. G. C. Darwin also spoke, and Professor Gray, in concluding the certainly instructive discussion, remarked that he did not wish to leave time and space severely alone, as had been proposed.

THE LIMITATIONS OF RELATIVITY.

In a note on "The Limitations of Relativity," by Mr. W. J. Johnston and Sir Joseph Larmor, M.P., F.R.S., which was read by Professor Gray, the authors considered three propositions as valid:—(1) A field of physical activity possessing the two characteristic properties, that the quantities defining it were propagated through the ether with a single constant velocity, and that translatory uniform convection through the ether produced no modification in the field, would necessarily be restricted to Maxwell's type of electro-dynamic field; (2) A field of gravitation would be included as to the limiting forms of such a type when the velocity became very great; since like source attracted like, the energy of the field should be kinetic, not elastic; but the question of interaction between a field of gravitation and an electric field or rays of light was a separate one, independent of theories of relativity; (3) If time were linked with space after the manner of a fourth dimension, relativity would be secured as above, but the sources of the field could not be permanent particles or electrons. If physical science were to evolve on the basis of relations of permanent matter and its motions, time must be maintained distinct from space, and the effect of convection must continue to be thrown on the material observing system in the form of slight modification of its structure.

THE ETHER AND THE PERIHELION OF MERCURY.

In this paper Dr. R. A. Houstoun, of Glasgow, said that Sir Oliver Lodge had unsuccessfully attempted to explain the progression of the perihelion by assuming the mass of Mercury to be given by the formula $m_0/(1-v^2/c^2)^{\frac{1}{2}}$ where v was the velocity of Mercury relative to an ether at rest in space and the mass was supposed to vary like the mass of a kathode particle. Dr. Houstoun thought that the optical difficulties associated with the earth's motion through space would best be met by assuming that the ether was geocentric, and had the same velocity of translation to the uttermost corners of space as the earth had. Accepting, then, Eddington's orbit and Lodge's mass of mercury, but regarding v as the velocity of Mercury relative to the earth (the ether moving with the earth), Dr. Houstoun arrived at Einstein's formula for the perihelion motion, but he had a factor 2, instead of Einstein's 12, and his result was only one-sixth of Einstein's, therefore; the agreement would be perfect if the mass of Mercury varied six times as fast as the mass of a kathode particle. Sir Oliver Lodge's comment on the paper was that he had not been unsuccessful, but rather too successful for the astronomers. Professor Gray was afraid we could not supply each planet with an ether of its own velocity, an assumption which Professor Eddington, however, was willing to accept,

THE INTERPRETATION OF THE QUANTUM.

In his second paper Dr. Houstoun suggested that the apparently revolutionary character of Planck's quantum could be tolerably explained by the use of the ordinary model atom, consisting of a sphere of positive electricity of uniform density with one electron inside oscillating about its centre through the positive charges. Calculating the velocity v, which the electron would require in falling from the surface of the sphere to the centre, Dr. Houstoun found that the formula was of the form of the formula for the quantum of kinetic energy, the two formulae differing only by $\sqrt[4]{v}$. The two values of v would, for yellow sodium light, be nearly equal, but his formula gave only one-fourth of the correct value for the X-ray region; the agreement was sufficient apparently, he considered, to justify the assumption that the quantum was the energy acquired by the electron in falling into a void atom. Discussing this paper Dr. Lindemann stated that such relations had repeatedly been suggested by Nernst and himself, and that the agreement was more satisfactory where a blue spectrum line was selected; the trouble was, however, that a suitable model could not be obtained.

THE SUN AS A MAGNET.

Sir Joseph Larmor had sent in a paper entitled, "How could a Rotating Body like the Sun become a Magnet." In Sir Joseph's absence the paper was not discussed; the considerations are of a very comprehensive character, and we hope to publish the paper later.

THE SPECTRUM OF NOVA GEMINORUM.

Lieutenant-Colonel F. J. M. Stratton, of Cambridge, exhibited a fine series of photographs of the Nova Geminorum, taken at different periods within a year, and suggesting by their changes a series of outbursts and pulses. The first spectrum taken before the Nova had attained its maximum brightness was an absorption spectrum of hydrogen showing enhanced lines of calcium, iron and titanium displaced towards the violet by amounts varying on different dates; iron lines were accompanied by radiation bands slightly displaced to the red. When the position of the lines had become more normal in a course of days, a second pulse seemed to have occurred, the absorption spectrum then consisting mainly of oxygen, hydrogen, helium and carbon, the displacements, again to the violet, indicating velocities up to 960 per second against 570 km. in the first pulse. In the third pulse the gases reached apparently the enormous velocities of 1,800 km. per second, and the velocities seemed to increase instead of decrease in the course of days as they had done in the first two pulses. Then bright bands appeared in positions corresponding to the former absorption bands; the bands, of several elements, had the great width of 24 tenth-metres and were only slightly displaced towards the red; the nebulium line made its appearance, the bright bands of hydrogen and helium of nebulae predominated, and finally the bright band spectrum gave way to the lines typical of Wolf-Rayet stars. In the early stages certain dark lines of sodium, calcium, and also of hydrogen were undisplaced. There were other peculiar features. The hydrogen bands at one stage showed the bright centre of the width mentioned above with fainter wings at each end, the cosmys doubling the whole width; in the bright centre two maxima were distinguished, the one displaced to the red, the other to the violet from the centre. Though the displacements of the various lines differed in different pulses, all the maxima displacements were proportional to the wave-lengths, and they hence seemed to be due to the motion of the constituent in the line of sight. Such velocities persisting for many months were difficult to understand, even when we thought of outbursts of gas from the centre of a star into a relatively quiet outer atmosphere and a gradual passing of the streamers into circulation. On the other hand high velocities were familiar to the experimenters with discharge bulbs; but the closer study of the spectra, especially of the winged bands and of the separation of the several hydrogen lines, did not support the suggestion of electric forces and of highly-charged atoms impelled at high speeds, or of Zeeman and Stark effects. The lighter gases seemed to be moving faster than the heavier gases, and we were driven back to the assumption of gas outbursts and complicated rotation and convection currents, without being able to account for the cause of the outbursts of new stars.

THE PROGRESSIVE SPECTRA OF NOVA AQUILAE.

The Rev. A. L. Cortie, S.J., following with this paper, said a few words in explanation of the term A and B types of stellar spectra used by Dr. Stratton. Astronomers spoke of spectrum types G (our sun), F (calcium stars), A (hydrogen stars, Sirius), B (helium stars), and Wolf-Rayet stars and nebulae, but the G. F. A. B stars (and sub-classes) might be low-density giants of ascending temperatures, or high-density dwarfs of temperatures descending in the order mentioned. The Nova Aquilae had been known as a star of the eleventh magnitude; by June 10, 1908, its magnitude was 0; a rise of 10 magnitudes meant 10,000 times the brightness, and the star had continued to increase in brilliancy at the rate of 2·4 times per 24 hours between June 8 and June 10; then it fell off to magnitude 3 or 4 by June 30, and at present the magnitude was 7 or 8. His first (slit) spectrum of June 10 showed a transition between dark and bright types of spectra, with lines of hydrogen and calcium, resembling the α Cygni type (between F and G); the displacements of the various hydrogen lines corresponded to the enormous velocities of 1,760 km., 2,400 km. and 2,716 km. per second, velocities two and three times greater than those observed in prominences. In a few days the spectrum changed, the dark lines died out and the bright lines asserted themselves; by June 15 the dark lines were faint and the nebular character became more noticeable; a nebular band was, in fact, visible in the earliest stage by June 29; by June 29 the bright lines of oxygen, nitrogen and helium were prominent, and the nebula seemed to cool; in October, 1918, the bright bands were still of the same character, and his latest very faint spectrum of August, 1919, still bore the appearance of a Wolf-Rayet star or nebula. In its spectral history the Nova Aquilae thus resembled the Novæ Persei and Geminorum and other new stars. The triple character of the bright hydrogen bands might be a Zeeman effect. It was not necessary, perhaps, to ascribe the displacements altogether to a motion in the line of sight. The whole phenomena suggested an outburst from a giant star in a dark nebula, setting the nebula into luminous vibration; when these died away the nebular spectrum remained, on which the chromospheric outburst lines had been superposed. Col. Stratton remarked during the discussion that experiments made at Mt. Wilson and elsewhere seemed to exclude the possibility of a Zeeman effect.

SPECTRA OF ATOMIC SYSTEMS WITH COMPLEX NUCLEI.

The important general considerations which Dr. L. Silberstein submitted on "Spectrum Emission of Atomic Systems containing a Double or more Complex Nucleus," extend Bohr's new theory of spectra (since 1913) in a way which did appeal to mathematicians as well as to the many who were unable to follow the mathematical deductions. So far, Sir Oliver Lodge remarked afterwards, all the theories of the emission spectrum had dealt with a point nucleus of the atom; but the nucleus must be complex, and Dr. Silberstein's complex nucleus helped us over many difficulties. Bohr's hydrogen atom, Dr. Silberstein pointed out in his communication, consisted of a simple nucleus of positive electricity round which an electron oscillated in circular orbits of various radii; the electron did not radiate while describing its regular orbits, but radiated when falling from one orbit into another. The novelty of Bohr's later theory was that he had applied the quantum theory to these considerations and thus accounted for the lines of the Balmer series. But the hydrogen lines were doublets, and the fine structure of its spectrum (disclosed by Paschen's measurements which Dr. Silberstein considered as the most reliable) had been explained by the relativistic refinements of Sommerfeld (München) and by Epstein (Stark effect). To explain the second (multilinear) spectrum of hydrogen and other spectra, however, Dr. Silberstein had applied the quantum theory to the three-dimensional problem of a complex (Rutherford) nucleus; he then obtained the great variety of elliptic and hyperbolic orbits which the complexity of the spectra demanded, and Balmer's law appeared only as a special simple case. The first simplest case he considered was that of a nucleus consisting of two positive centres at distance $2a$, the case of the Euler-Jacobi problem; the physically most interesting case of comparatively large orbits was treated by the method of perturbations. From the frequency interval between the lines of the hydrogen doublets he deduced the value $2a = 3 \times 10^{-13}$ cm., for orbits possibly of the order of 10^{-8} cm. Dr. Silberstein also gave formulae for any axially-symmetrical nucleus and referred finally to the general case of any arbitrarily-charged nucleus. One of the suggestions he threw out was that apparently enormous velocities in the Novae (mentioned in the papers by Stratton and Cortie) might be due to changes in the nuclei.

During the discussion Sir O. Lodge pointed out that elliptic (instead of circular) orbits of the electrons round an eccentric nucleus would make radiation on the Newtonian principle possible, since the speed would vary in different portions of the orbit. Professor Whitehead commented on the radiation formulae.

(To be continued.)

RECENT MACHINE TOOL DEVELOPMENTS.—No. VI.

By Joseph Horner.

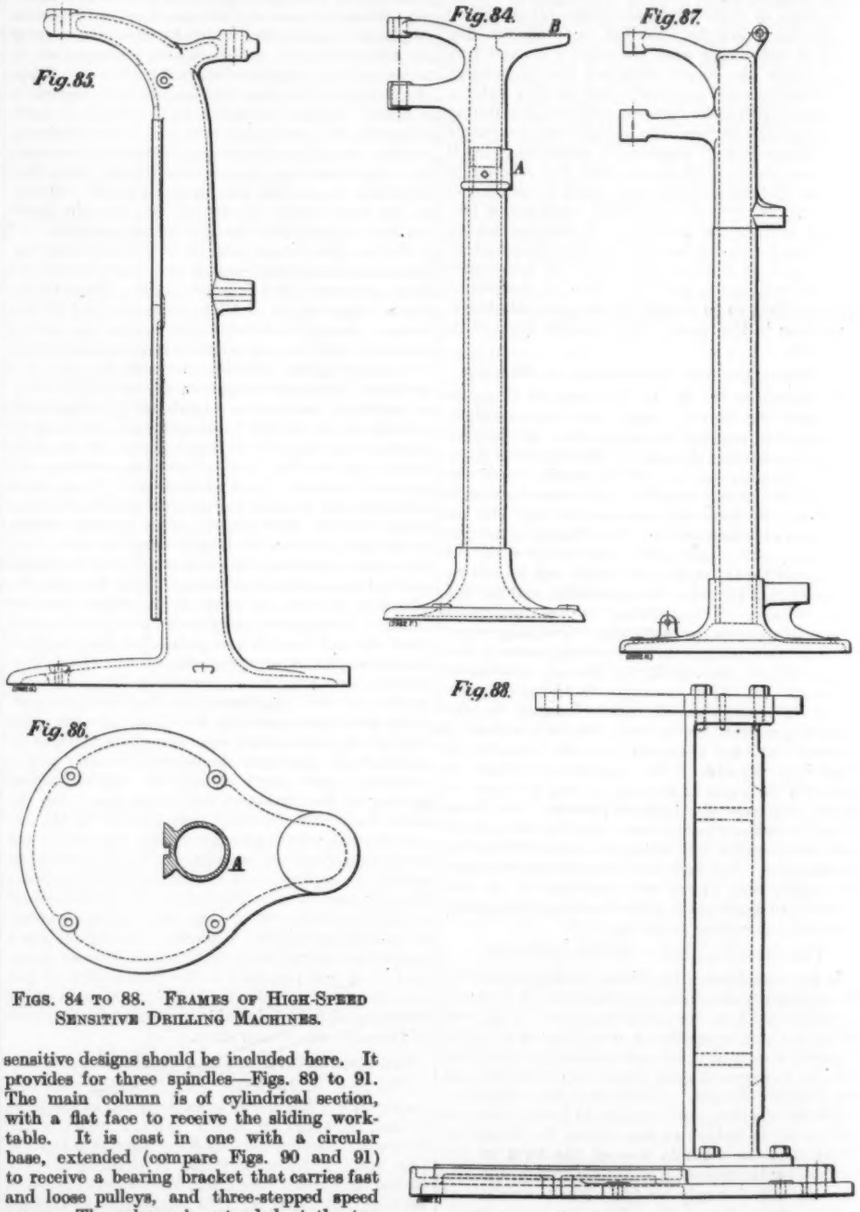
High-Speed Sensitive Drilling Machines.—A simple design of frame for one of the A. Herbert machines is shown by Fig. 84. The lower portion is a hollow cylindrical column, cast with its broad spreading circular base. The upper part is a separate casting registered over the top of the lower one. Two brackets are bolted to it—one on the vertical facing A, to receive the fast and loose driving pulleys, the other above at B, to carry the belt-guide pulleys, this one having a long slot hole for the bolt to permit of tightening the belt. The bosses for the drilling spindle are cast solidly. In the interior of the hollow pillar a balance weight is suspended, which is connected by a wire rope to the table outside, to counterbalance the latter. This is done because the table has no elevating gear, through rack and pinion, which the heavier machines have, but is merely adjusted by hand on the column. The boss of the table encircles the column, on which it is clamped with a bolt and lever, through a split lug.

A design of framing for a larger machine is seen in outline in Figs. 85 and 86. Stability is assured by the extent of the base, of which Fig. 86 shows the plan. The column section is seen at A. It is mainly circular with a flat slide face, and vee'd edges to receive the adjustable spindle head, and the work-table. The base receives at its right hand a bracket that carries fast and loose pulleys and the driving belt cone. A bracket to be attached to the foot at the left, carries a foot lever that throws over the belt between fast and loose pulleys. The boss located rather more than half-way up the column carries the shaft on which the driven belt cone pulleys revolve. The bracket at the top carries the shaft for the tension guide pulleys, adjustable by vertical movements. The single boss at the front receives the driving shaft to the spindle, the lower end of the drilling spindle being supported in a bracket that slides, and is adjustable on the front guide ways of the column, Fig. 85. This bracket is counterbalanced, the weight being suspended within the column, and it is clamped when set, the feed being put on with a cross-handle, rack and pinion. The work table is carried on the vee'd ways below, and is adjustable vertically by rack and pinion, the rack fitting in the recess seen in the plan Fig. 86. When the table is positioned, it is clamped with a simple lever, tightening a gib against one of the vee'd edges. This design, therefore, differs in all its details from the previous one.

Fig. 87, a Webster and Bennett design, has the circular base separate from the column. The latter with its brackets is one casting stepped into the base. It is parallel for a certain distance, to the highest range of the work-table, the boss of which encircles it, and which is secured with a single clamping bolt in a split lug. The diameter above is reduced slightly, and the thickness of metal is lessened. The table is adjusted by hand alone and its weight is counterbalanced, a wire rope passing from it over a pulley at the top to a balance weight suspended within the column. The right-hand boss cast on the base receives the shaft on which the fast and loose pulleys and the stepped cones run. The left-hand boss is the fulcrum for the foot lever for the striking gear of the fast and loose pulley belt. A boss on the reduced diameter of the column receives the shaft for the driven cones, and one at the top, that for the tension guide pulleys.

A good many sensitive drills are built with short columns, to be mounted on benches. The working parts are identical with those used on floor machines. Height is lessened, but the reduced capacity suffices for the requirements of many shops, and the design is valuable from the point of view of gang-drilling on repetitive work, for which several machines can be arranged in a row. Fig. 88 is a framing of a sensitive bench drill. The column is bolted to a table, which has a waste lubricant trough surrounding. The lower head for the spindle is made to slide on the front face of the column, on which, after adjustment, it is clamped with a central bolt and a locking handle at the rear. A flat plate is bolted on the top to receive the upper bearing boss for the drill spindle and a bracket that carries the guide pulleys for the belt. Machines of later design discard the plate, and have the upper spindle bearing of curved outline cast in one with the column, as in the examples immediately preceding. The lower cone pulleys are carried on a fitting on the base, which provides the tension, or on a bracket at the back of the column.

So many multiple spindle machines are now in use that an illustration of the framing of one of the



Figs. 84 to 88. Frames of High-Speed Sensitive Drilling Machines.

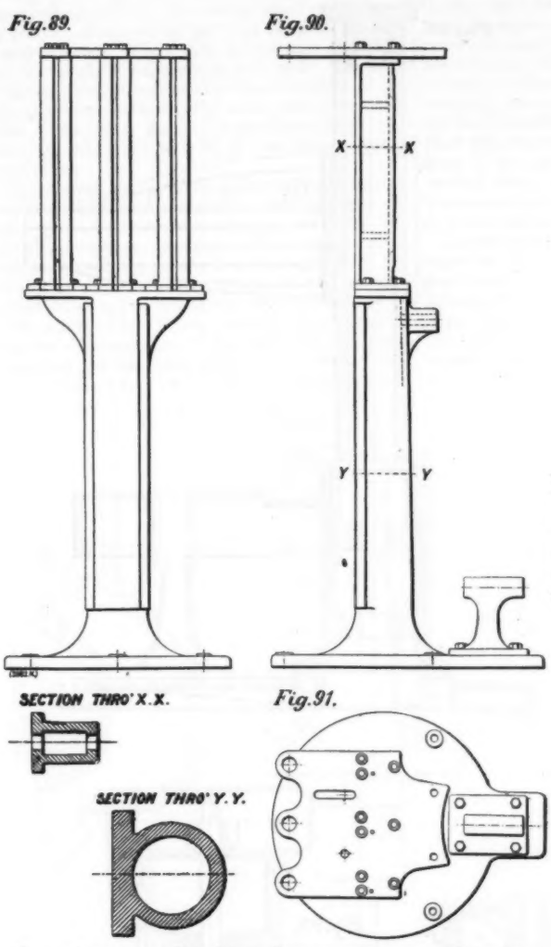
sensitive designs should be included here. It provides for three spindles—Figs. 89 to 91. The main column is of cylindrical section, with a flat face to receive the sliding work-table. It is cast in one with a circular base, extended (compare Figs. 90 and 91) to receive a bearing bracket that carries fast and loose pulleys, and three-stepped speed cones. The column is extended at the top into a platform to receive the three-spindle bearing supports bolted to it. These are hollow castings of rectangular section, pierced at back and front for the clamp bolt that grips the lower sliding spindle head. The uprights are tied at the top by the plate which carries the drilling spindles, and those for the belt guide pulleys. In later machines the arched head for the top spindle bearing is cast with the columns, and the columns are of circular section with flat faces for the sliding spindle heads. As the lengths of work tables must be extended with increase in the number of spindles, support is afforded underneath with a telescopic screw in the large machines.

The Radial Arm Group.—Very broadly, subject to many variations, the radial drilling machines, so far as the column and arm are concerned are built on two models. In the first and earliest the fulcrum of the radial movement of the arm lies outside the axis of the supporting pillar or column, in the second it coincides with this axis.

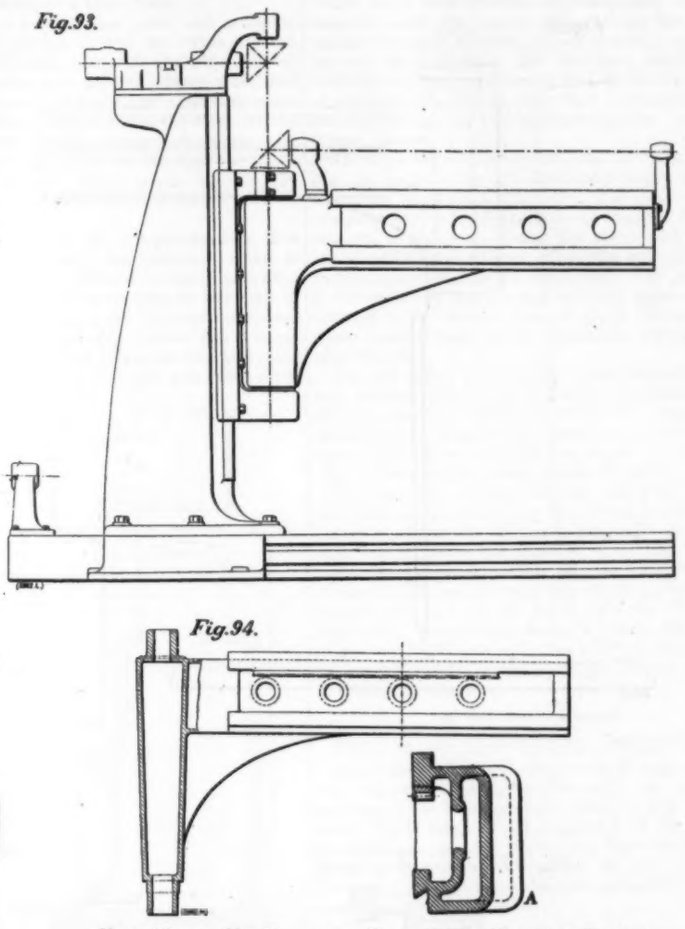
The Eccentric Axis Designs.—In these the column receives on slide ways on its front face a saddle having vertical adjustments through a screw that is power-operated. The saddle has capped trunnion bearings at top and bottom, in which the journals of the radiating arm swivel. The shape of the pillar favours stability, tapering well from the spreading base upwards. The very long and broad slide, with its vee'd edges, and gib, the large trunnions situated far apart, the arm nearly immune from drop, or upward thrust by the curved bracketing, and in many, by its parabolic outline, were all conducive to rigidity under the relatively light drilling pressures of the long years when no other designs were in use. The weak point is the pivoting of the arm in trunnions that stand away from the column, and having two distinct sets of fittings, to develop possible slackness.

Early Whitworth Machines.—Fig. 92 is a photograph of a Whitworth machine taken in 1868.

RECENT MACHINE TOOL DEVELOPMENTS.



FIGS. 89 TO 91. HIGH-SPEED SENSITIVE DRILLING MACHINE.



FIGS. 93 AND 94. EARLY AND TRANSITIONAL FORMS OF RADIAL DRILLING MACHINES.

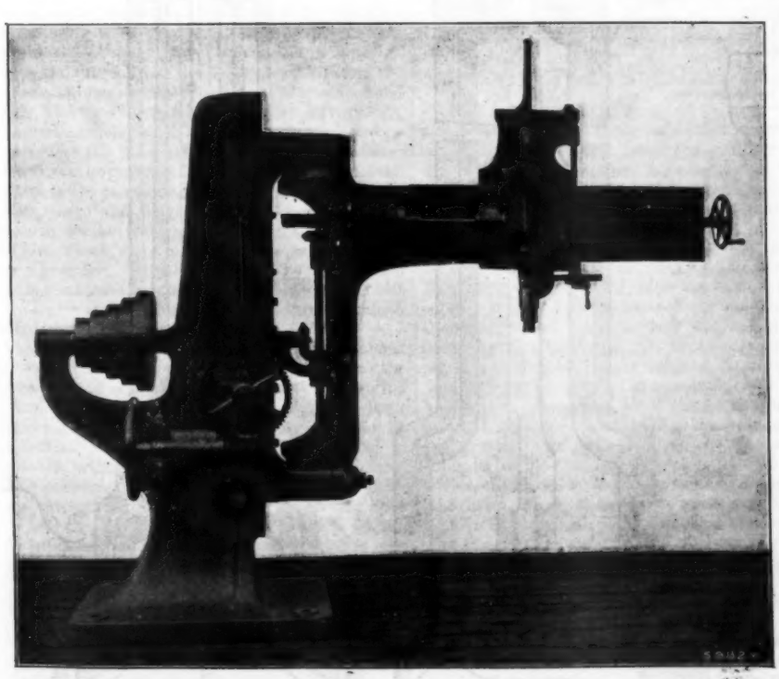


FIG. 92. EARLY WHITWORTH RADIAL DRILLING MACHINE.

For thirty years after, this was in its main features the only design seen in machine shops. The upright was of boxed section, and the long trunnion slide was adjusted vertically by the hand wheel and worm gear actuating a pinion on the wheel shaft that engaged with a rack on the back of the slide. Power-elevating gear was not fitted until long afterwards. Five belt speeds were transmitted through bevel gears to the telescopic shaft in the radial arm. The feed gears on the saddle were actuated by worms and tangent wheels, but power was not provided. Neither was the spindle counterbalanced.

More than twenty years earlier than this, a patented Whitworth machine was illustrated, in which, while the main outlines were nearly identical with those shown in Fig. 92, the spindle (counterbalanced) was fed by a scheme that was a favourite with its inventor, since he applied it to other drilling machines. A thread was cut on the drilling spindle equal in length to the total feed, and this was embraced by two screw nuts on opposite sides—small hollow-faced worm wheels, which during the revolution of the spindle caused it to feed downwards. The upper edge of the radial arm was of parabolic outline. It is stated that the radial design of drilling machine was due to Messrs. Benjamin Hick and Son, of Bolton.

Fig. 93 may be regarded as representative of the early design when now retained in use. The differences hardly concern outlines at all. There is the parabolic form of pillar bolted to the base, receiving the vertical slide, in which the radial arm is pivoted. The real differences are those in the methods of transmitting the speeds and the feeds, which only slightly affect the framework. The

RECENT MACHINE TOOL DEVELOPMENTS.

Fig. 95.

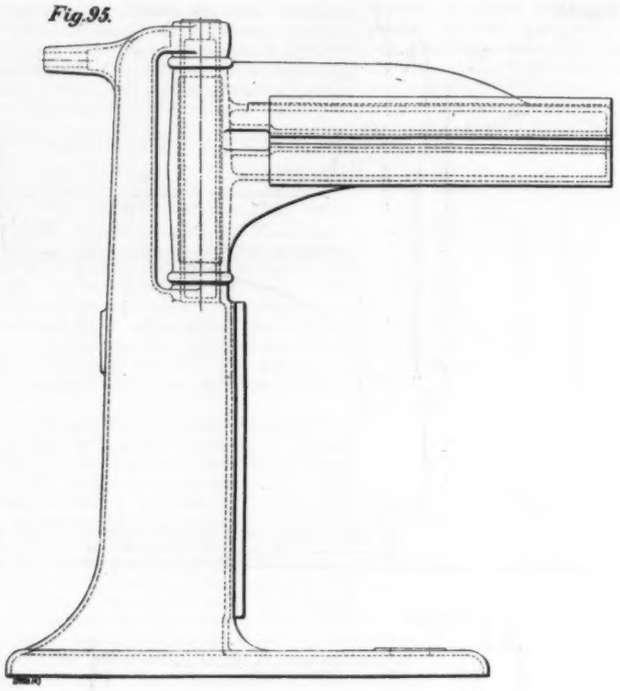


Fig. 96.

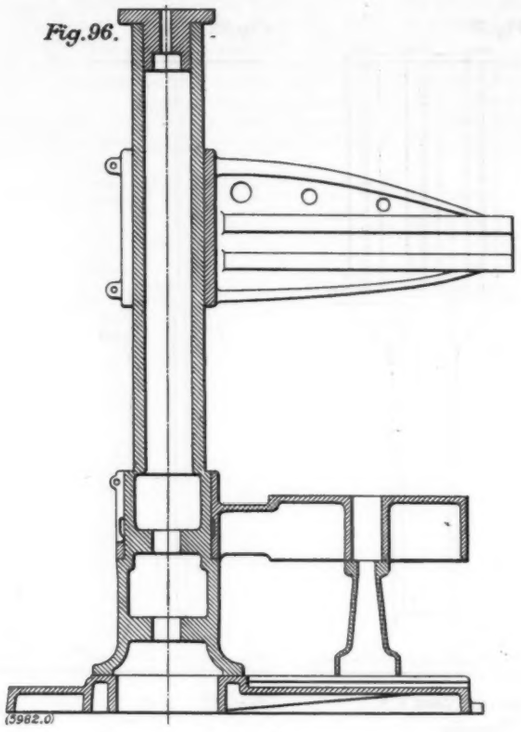


Fig. 97.

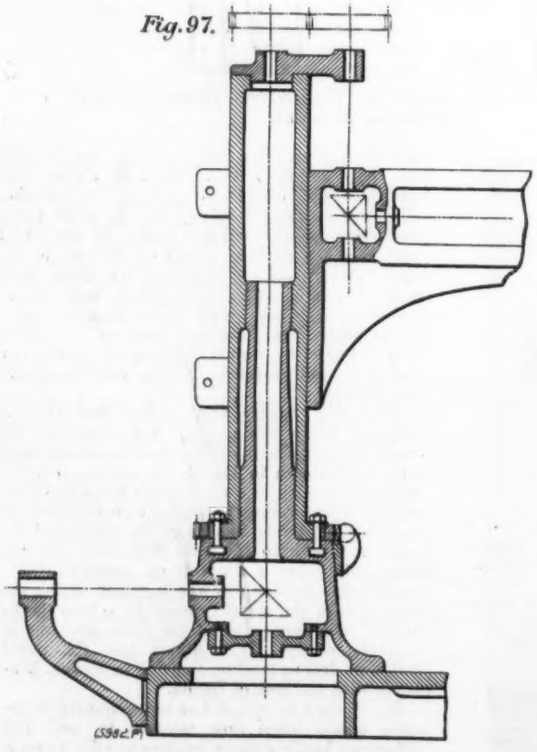


Fig. 98.

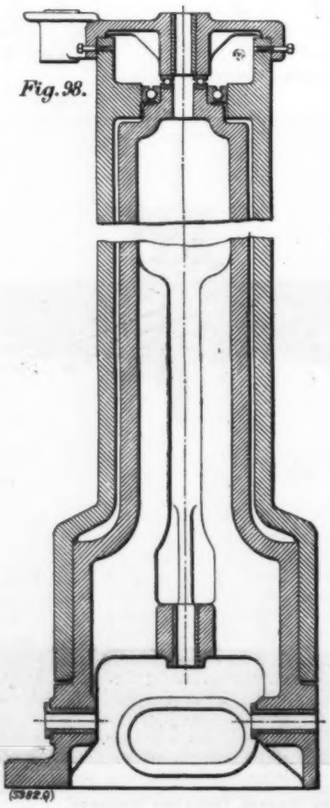


Fig. 99.

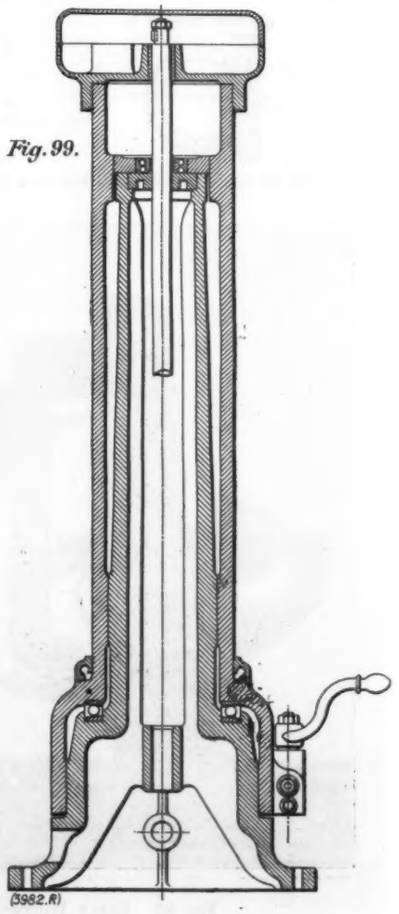


Fig. 95. Framing of Radial Drilling Machine, by Messrs. F. Pollard and Co., Ltd., Leicester. Figs. 96 to 99. Examples of Frames of Radial Drilling Machine of Central Axis Design.

main driving pulleys are carried low down on the base, and these drive to cone pulleys mounted on top of the pillar, whence through mitre gears the spindle is driven. The arm is raised and lowered by power. Feeds are by power or by hand, through a nest of gears. The saddle is traversed along the arm by hand, through pinion and rack. The base of the machine is continued to the full length of the arm to receive work directly, or on an intermediate table. But this design, notwithstanding the improvements built into it, is not now regarded favourably.

Transitional Forms.—The radials next illustrated may be regarded as transitional, although they are well-approved present-day designs, rivals to the cylindrical column machines. The vertical slide with its trunnion bearings is abandoned, with the advantage, that the axis on which the arm radiates is brought nearer to the axis of the main column.

The design of arm in Fig. 94 only departs slightly from the old standard. It terminates in a tapered cylindrical outline, with trunnions to fit bearings in a vertical slide. The elevation is effected by a vertical screw stepped into the base of the machine, and entering a screwed bush within the bottom trunnion. Reversing bevel gears and a train of spur gears, driven from the belt cones carried on the base effect these vertical movements through a hand lever. The machine is of high-speed sensitive design, the spindle being belt-driven. The tapered outline imparted to the pillar corresponds with the greater stress that is imposed on its upper sections. Though the arm is not parabolic, it is reinforced with a large radius where the diagonal stress is most severe. The arm section shown at A, is illustrative of a detail to which much attention has been given in recent practice. In this example, the solid-plated back is reinforced by a mid-rib, lightened with holes at intervals along the neutral axis, through which the core is removed.

Fig. 95 illustrates the framing of a 36-in. machine, by Frederick Pollard and Co., Limited. Here the arm is pivoted on a stout cylindrical stem, inserted in the column, put in from the top. Its large journals afford good wearing surfaces. Necessarily the vertical range of movement is transferred to the table, which slides on the ways on the front of the column. In this size of machine the table has a vertical range of 12 in. and the drilling head of 8 in. As the overhang of the table is 34 in., it is supported on a step, for which a facing is seen provided on the base. It is elevated by a hand lever and mitre gears, turning a screw in the base. The framing shown is adopted by the firm for machines of various capacities, high-speed, gear-driven, and belt-driven sensitive. The largest machines are provided with a stay to connect the end of the arm with the end of the table.

Central-Axis Designs.—In these, by far the larger group now built, the boss of the radial arm embraces the column, and swivels round, axially. The column, though parallel, is rendered stable by the support afforded by a broad base.

An example of a cylindrical pillar, and a double parabolic arm is shown by Fig. 96. This has the advantage of affording increased stability, and of ensuring a steadier grip on the column when the clamping bolts are tightened than is the case when the boss is shallow. In this design the main driving shaft goes up through the centre of the pillar, and from it, through spur gears at the top, driving a vertical shaft outside, mitre gears actuate the horizontal shaft, whence the drilling spindle receives its speed changes.

Another framing, Fig. 97, is representative of a large and favourite group, the feature in which is the rotation of an outer cylinder or sleeve round the actual pillar carrying the arm with it, although in large numbers of instances the arm and sleeve are one casting. The supporting column has a large circular base, and a foot bolted to the baseplate within which are enclosed the mitre gears that drive a vertical shaft, whence through other gears the arm is adjusted vertically, and the drilling spindle driven. The supporting column is of conical outline with thicker metal at the base than above. The sleeve is rotated by worm gear, and locked. Usually, ball bearings are fitted.

Fig. 98 is a vertical section through the latest design of radial drill column, by the Cincinnati-Bickford Tool Company. Here the inner cylindrical column is bolted to the base of the machine, while the outer sleeve that receives the radial arm is fitted by grinding over the much-enlarged lower portion, and embraces the reduced diameter at the top, through the medium of an annular ball bearing, which is supplemented by a thrust bearing. The internal ribbings shown stiffen the column where the greatest stresses are imposed. The sleeve is clamped on the enlarged portion of the column, with a choice of two methods, hand and pneumatic. The hand clamp includes an eccentric shaft and bolt, pulling on both horizontal, and vertical splits. The compressed air clamp is operated by a lever that travels with the drilling head, and requires an air pressure of 70 lb. for its operation.

Fig. 99 is a section through the column made by the American Tool Works Company, of Cincinnati. Here the column is enlarged at the base to receive the sleeve. It is ribbed internally, has a second bearing well up towards the centre, and the sleeve is supported by a ball race at the bottom, and is centralised at the top by a radial bearing having double rows of balls.

Arm Sections, and Central Thrust.—All the early radial arms had sections approximating to the letter D, with the saddle sliding along the front upright face, and the drill spindle standing out well beyond that. This is not the best form, and developments have proceeded first, in the direction of stiffening the design, and then in resisting the pressure of drilling within the arm—the "central thrust."

An improved section of arm was shown at A, in Fig. 94, another, by the Cincinnati-Bickford Tool Company, is given in Fig. 100. The section is a complete box, save for the holes at the back for the removal of the core. Deep ribs above and below afford additional stiffness. This arm embodies the narrow guide—the lower slide way. The take-up is between the vee'd edge and the square edge opposed to it, where a tapered gib is fitted. The upper square edge shows clearance, with a flat retaining gib.

Fig. 101 shows the Asquith central thrust radial arm section. The arm is boxed, embracing the drilling spindle between its walls, and the saddle slides along bottom ways instead of on a vertical face. The arm is cast with the sleeve, and the top edge of the arm has a deep parabolic outline.

Fig. 102 is a section through the arm of the machines manufactured by the Selson Engineering Company, Limited. The arm, parabolic along the top, is a complete box (shaded in section) except along the range of opening for the drill spindle. The saddle fits on the front face and is gibbed both on the vee and at the back, so that tilting is impossible. The spindle bosses are seen above and below, also a half bearing for the shaft that transmits the speeds to the spindle, and the bosses for the feed-shaft mechanism.

Fig. 100.

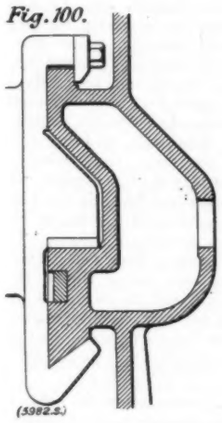


Fig. 101.

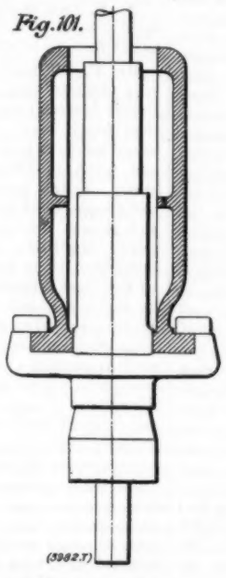
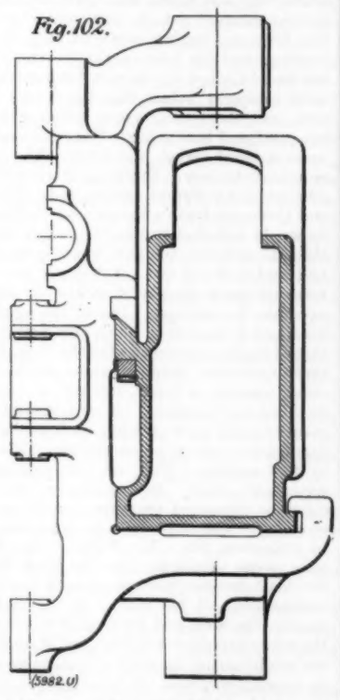


Fig. 102.



THE IRON AND STEEL INSTITUTE.

As stated in the short article which appeared in our last issue (*vide* page 384 *ante*) the autumn meeting of the Iron and Steel Institute was opened at the Institution of Civil Engineers on Thursday, the 18th inst., and the preliminary business already reported having been disposed of, the meeting proceeded with the reading and discussion of the papers on the programme.

FUEL ECONOMY AND FUEL CONTROL.

In the course of his introductory remarks on this vital question, the chairman, Sir Robert Hadfield, stated that the stoppage of coal supplies for both manufacturing and domestic purposes, would be of most serious moment to Great Britain. It was hoped that the papers then to be presented at the meeting on the subject of fuel economy would arouse attention to this very important question. Some time ago, when President of the Society of British Gas Industries, he offered a prize of 100*l.* for the best essay on "Fuel Economy," whether as regards lighting, heating or melting, There was quite a keen competition, and the prize was eventually awarded to Mr. F. W. Epworth, of the Richmond Gas Stove & Meter Company, Warrington. From the data given in Mr. Epworth's essay, the diagrams given in the joint paper by himself (Sir Robert) and Mr. Sarjant, of the Hadfield Research Laboratory, had been prepared. He (Sir Robert) was so pleased with the results of the prize essay competition referred to that, after conversation with Professor W. A. Bone, he brought the subject before the Council of the Iron and Steel Institute, and suggested that it would be desirable to thoroughly discuss the subject. The Council quite approved, hence the introduction of the question at the meeting now being held; he hoped useful results would follow from the papers and discussions. He had dealt at some length with the subject in his presidential address to the Society of British Gas Industries in April, 1918, of which 1,500 copies had been widely distributed. He also brought the subject before the Federation of British Industries, as it seemed to him most desirable that by means of their widespread organisation, special emphasis should be laid both upon the scientific and the commercial side of fuel efficiency.

The Fuel Efficiency Committee of the Federation, consisting of 12 members, drew up a scheme of organisation, including the study of the conservation of fuel.

As regarded the training of skilled workmen, experience in his own company's works had been quite gratifying. If this question of fuel economy is placed properly before the worker, he quickly responds, and endeavours to assist his employer. It should not be forgotten that America and Germany had established important Fuel Research Institutes and Bureaus.

During the discussion of the Report of the Fuel Research Board before the British Association at Bournemouth recently, Sir Charles Parsons gave very strong assurance that our own Fuel Research Board, over which Sir George Beilby presides, was hard at work, and would soon be in a position to give a helping hand. As the Board will soon have spent about 100,000*l.*, there was no doubt it would be largely instrumental in assisting to solve the many problems presented to us.

Here, Sir Robert recommended to the members a most able report on "The Energy Resources of the United States: A Field for Reconstruction," by Messrs. C. G. Gilbert and J. E. Pogue, of the Division of Mineral Technology, United States National Museum (Bulletin No. 102, vol. I., Smithsonian Institution). In regard to the coal output per man being so much higher in America than in this country, it should not be forgotten that many American colleries were not hundreds of yards, but only hundreds of feet in depth; also many of them were open workings.

Finally, Sir Robert called attention to the excellent Fuel Laboratory at South Kensington, which was presided over by Professor Bone, who, he felt sure, would be only too glad to give any assistance possible to those wanting information.

Report on Fuel Economy and Consumptions in the Manufacture of Iron and Steel.

This report, by Professor W. A. Bone, D.Sc., F.R.S., Sir Robert Hadfield, Bart., F.R.S., and Mr. Alfred Hutchinson, M.A., was then read in abstract by the former, who stated that it was presented to the Institute on behalf of the British Association Fuel Economy Committee, of which he (Professor Bone) is the chairman, because it was thought that the subject would perhaps have a more complete discussion by members in the iron and steel trade, at one of the Institute's meetings, than it could have in Bournemouth. Professor Bone stated that all the figures in the report on fuel consumption were per ton of ingot rolled into finished sections. We need not refer specially to the report here; we commenced its reproduction in our last issue, and conclude it in the present one.

Sir Robert Hadfield then read a letter from Sir George Beilby, who regretted he could not be present at the meeting; he had been asked to represent the Royal Society at the Watt Centenary at Birmingham.

W. A. Hutchinson, as one of the joint representatives of the Institute on the Fuel Committee, said he could not be expected to speak on the report before the meeting; he desired, however, to say that the Committee were extremely grateful to Professor Bone for the large amount of work he had carried out in the drafting of the report in question, which was one for general discussion at the meeting.

Report on the Present Status of Fuel Economy in the German Iron and Steel Industry of the Occupied Territory on the Left Bank of the Rhine.

This report by Mr. Cosmo Johns and Mr. Lawrence Ennis, was then taken, and was read in abstract by the former. We reproduce it on page 428 of our present issue. In the course of his remarks, Mr. Cosmo Johns said that in this country we had not great faith in blast furnace gas engines, whilst in the provinces dealt with in the report such was not the case. Our gas engines here had been too small, as compared with those working in Lorraine; there, the newer the works, the larger were the gas engines. Further, he had not seen in the districts visited any real active mixer, in which metallurgical operations were carried out; the mixers were simply containers, and if heat in comparatively small amounts were supplied to them, this was simply to maintain the slag liquid. The soaking pits were also plain soaking pits. For one engine on coke-oven gas there were 100 on blast-furnace gas.

Fuel Control in Metallurgical Furnaces.

This paper, contributed by Sir Robert Hadfield, Bart., and Mr. R. J. Sarjant, M.Sc., was then read in abstract by the latter. We reproduce it on page 425.

The discussion on these three papers was opened by Mr. B. Talbot, who stated that all consumers of coal were greatly indebted to the authors, especially to Professor Bone, who, for the last five years, had ably and persistently called attention to our shortcomings in the respect of coal consumption. We used more fuel than was necessary, but he (the speaker) did not know that the iron and steel manufacturer could be blamed entirely for that. The papers were based upon the prime movers being large gas engines. During the war, nothing new could be attempted; all the work carried out everywhere was war work, and that class of work was not the cheapest or best. Some years before the war, the first gas engine came to this country from Seraing, and his (the speaker's) firm were among the first to adopt it; he put down seven, but these were scrapped before the war broke out. They then had the second type, which was ultimately scrapped and broken up. They were now engaged upon a third series, and hoped this would prove more satisfactory. Professor Bone had taken his (the speaker's) figures arrived at in 1917; both his and Professor Bone's figures practically agreed, but he would add that it was not always safe to take a theoretical figure, and that was why he (Mr. Talbot) had added the 2 cwt. of fuel per ton of finished material for a margin of safety, to make up, for example, for leakages. One of the most important questions to meet was, in his (Mr. Talbot's) opinion, that of linking up plants. On the Tees, for instance, there were five plants in close proximity to each other, owning a large number of blast furnaces working continuously; it was possible for those plants to link up for pooling their available gas and supplying a central power station. This would lead to fuel saving. This was, he repeated, a most important point; but the mere fact that such concerns remained separate should not stop fuel economy. The same remarks were also applicable to coke-oven gas. Mr. Talbot believed that the coke ovens should be near the blast furnaces, for the blast-furnace manager should have the entire management of his coke. In the matter of gas supply, the week-end gas had to be considered. If the coke-oven gas could be stored, it could be used in the neighbouring district for lighting, and for domestic heating purposes. If the coke-oven gas produced was an ideal fuel, it opened up a point in the design of steel furnaces. The gas generators, a very expensive part of to-day's open-hearth furnace practice, could be done away with, and the units increased. He did not agree with one of Mr. Cosmo Johns' statements to the effect that the yield of the basic process was better than that of the acid; the comparison had to bear upon a first-class Bessemer basic with a first-class acid, then the yields would be found to be reversed.

Mr. A. Lamberton expressed the opinion that the problem of fuel economy was a most serious one to face at the present time. Professor Bone had said that all the figures for coal consumption in steel works were far above the 30 cwt. per ton, but in his Table V for firm No. XII the consumption was as low as 31 cwt.; this was a good record relatively. In regard to the engines, the meeting had heard Mr. Cosmo Johns' account of the gas engines in Lorraine and also Mr. Talbot's experience in the matter; the statements showed that things had to be proved "as we go." One point had not been hinted at and it was this. If all the new plant enumerated had to be used in order to obtain the economical results aimed at, would the saving realised in working this new plant pay the cost? The new plant would lead to a very large outlay. He asked whether the authors had looked into this question; to-day, it should be remembered, new plant would cost three times the pre-war prices. He hoped they would investigate that point of cost of new plant and of the returns to be expected from it.

Mr. Tennyson, speaking on behalf of the Federation of British Industries, said one scheme of the Federation was to develop methods of fuel economy. Firms and private persons were interested, and all the country and every industry were covered. The aim was to do for all British industries what Professor Bone's report aimed at doing for the iron and steel industry. The Federation divided the work under three headings: investigation, grading and allocation of the source of supply; investigating the fuel practice in different trades; and training the staff, acting in co-ordination with the universities for the training of experts. If any trade desired assistance, the fuel department would send an expert to investigate. A form of questions to be replied to would give the conditions of fuel consumption in individual instances, and would show how far these fell short of the standard. All this information would, of course, be treated as confidential. He hoped the Institute would help in carrying out the Federation's scheme.

Mr. E. Steer thought Mr. Lamberton had touched upon a point of view of practical importance which would have to be considered.

Mr. F. W. Harbord said the reports laid out very definite means of economy, and Professor Bone's essential conditions for attaining the practical ideal were all well known; many works would not have to make modifications to meet them, and many modifications would not be costly to make. In this country there were very frequently two groups, blast furnaces and steel works, separate, and it was practically impossible to bring these plants together. But assuming they were all assembled, there was no reason, for example, why all the blast furnaces should not have double bells. He had not heard of objections to the double bell. All were agreed on the dry cleaning of the gas. The concluding remarks in Professor Bone's report were very important; there were many things they mentioned which we could not do owing to considerations of cost, but our works could organise and it would pay them to have a man to look after leakages and to handle all things in this respect in a businesslike manner.

Professor Armstrong, who followed, said he welcomed the opportunity of speaking on the papers, although the only connection he had with iron had been through rusting. The problems which interested him were those connected with coal and with combustion. As far back as 1885, he had brought before the Institute the question of carbonisation of coal, and a few years later, at the Middlesbrough meeting, he had again spoken on the subject. In 1885 he had said that what had to be looked forward to was nothing less than the recovery from coal of the matters latent in it as completely as possible and in the most economical and advantageous manner and form. He had then stated that "we knew practically nothing of what happened when coal was distilled, or the conditions most favourable to the production of the valuable constituents of tar, and until we possessed adequate knowledge on these points the coking of coal and the manufacture of gas from coal and oil were empirical operations and could not be scientifically conducted. The aid of the chemist had to be sought, and the experiments had to be on a moderately large and therefore expensive scale. The interests involved were so great, the subject was one of such national importance, that the failure to initiate and execute the necessary systematic experiments without further loss of time was inexcusable." Very little progress had been made since he had given utterance to those words; a good deal had been done privately, but there had been no systematic research. The iron and steel industry had made the only real step forward in regard to the distillation of coal in producing coke for its use and in developing the recovery plant. He wanted to call attention to the part the industry was going to play in the future in providing coal tar, the material which was so very often spoken of in connection with the over-discussed dye-stuffs industry. The substances required were high temperature products; they were not to be got by low temperature distillation. He believed the iron and steel industry was going to be the only

high-temperature coking industry at no very distant date, and that the gas industry must be reformed, on new methods similar to those of supplying gas from the iron and steel industry's furnaces. Where that industry had coke ovens it ought to take on the gas industry; there ought not to be a gas company heard of anywhere near a blast furnace. From that point of view, the development of high temperature coke production was one of very great importance; it was hoped that the ovens that did not recover by-products would be got rid of at an early date. That was one of the things the Institute ought to set itself to do. In the gas industry enough coal could not be distilled to produce gas of a sufficiently high quality without producing a large amount of very poor coke not available for the iron and steel industry and also unsuitable for domestic use. Therefore, the gas industry had to alter; either to develop in such a way that it used a much smaller amount of coal and used the whole of that coal, or develop as a dependent industry in connection with others, with the electric light industry or in connection with a new industry to be developed for the production of smokeless fuel for domestic use. What had to be looked forward to, outside the iron and steel industry, was a complete change in the method of using coal. Great caution should be exercised in the matter of erecting large central power stations. One could not help feeling that this subject was not so definitely settled as the Government Commission Report would lead one to suppose. One or two of these great central power stations should be put in operation first for the purpose of gaining experience, and the Government should not at once proceed to convert the 600 stations scattered over the country into the 16 recommended by the Commission. As a centre for this experimental purpose Professor Armstrong suggested Nottingham; coal was near at hand, and there was a large district over which power could be distributed with advantage. He emphasised the need mentioned in the report of having men thoroughly educated to exercise control in works. He only knew of one firm which had a separate fuel manager, namely, Crossfield's, of Warrington. They had a man whose sole duty was to go about the works to see how the coal was being used and to ensure that it was being used to the best advantage; that had been a source of great economy to the firm. Men of that kind had to be educated, and that was not going to be an easy matter; their training had to be given by those who had some real understanding of the problem. Professor Bone's success in that matter had been very great. Here Professor Armstrong referred to his remarks at the meetings the preceding week at the British Association, and regretted that Sir George Beilby was not present at the Iron and Steel Institute meeting; nor had he been present at the British Association meetings. He would have liked to ask him whether he had a properly thought out programme of work. The iron and steel industry did not keep matters secret, and that was probably one secret of its success and the reason why it had made so much progress on the scientific side. When research was being carried on with national funds for national purposes, the first thing to be done was to put away all secrecy, and the Advisory Committee for Scientific Research had "cold-shouldered" everybody. No policy could be worse than one of secrecy on the part of a Government Committee.

Here Sir Robert Hadfield called attention to the apparatus of the Steere Engineering Company, Detroit, termed the "Tar Camera for Colorimetric Tar Determination," which seemed to be a valuable control instrument in gas works and works where by-products recovery or gas cleaning for power were followed. Sir Robert showed to the meeting a series of "tar pictures," obtained with it. The camera was made of aluminium, a metal which did not corrode, and was not affected by any of the constituents of the gas.

On the members re-assembling on Thursday afternoon, Mr. George Ainsworth occupied the chair, and Professor Louis said it had struck him that in the discussion no one had attempted to define "fuel economy." Obviously, the authors had meant several different things by it. One might mean getting out the maximum number of heat units in the fuel used, or getting out the maximum number of valuable by-products together with the heat units, or again getting out the maximum commercial results. As Mr. Lamberton had said, how much capital outlay would be required to obtain the particular commercial results aimed at? Then, which particular form of fuel economy was the best in the interest of the nation at large. He would like to see more said in the papers on the composition of the ores dealt with. It was not sufficient to say that the ore had 30 per cent. or 50 per cent. of iron. A 30 per cent. ore, the other ingredients of which were self-fluxing, was a very different proposition from the point of view of fuel economy, as compared with a 30 per cent. ore, the other ingredients of which consisted mostly of silica. The return could be made in several ways. Perhaps the best would be to state the total slag production per ton of pig-iron. Without those figures, it was very difficult to compare results. Taking Professor Bone's Table III., taking the total fuel used in the blast furnace, one would be justified in assuming that cold-blast melting was about the most economical. He was not suggesting that the deduction was a correct one; it only showed the necessity of having all the data before us, namely, the total burden and the total slag production in every case. More data were also wanted on calcination. Professor Bone referred to the amount of fuel used in calcining, but, in his basal diagram, that calcination was entirely omitted. It seemed *a priori* right to suppose that independent calcination of the ore before it went to the blast furnace was productive of fuel economy; but this should be done with the very cheapest form of fuel obtainable, in the interests of real commercial economy, as distinguished from thermal economy. He (the speaker) had been much interested in Mr. Cosmo Johns' reference to enriching blast, and experiments carried out in Belgium and Luxemburg seemed to confirm the possibility of producing considerable economies by that means. It was a point that required great attention, and he recommended it to Professor Bone's study. It seemed one of the possibilities of the future. He would ask Professor Bone whether he was absolutely clear in his own mind that the very best possible type of gas engine was that using blast-furnace gas. He (Professor Louis) was inclined to think that the best type of gas engine would be found to be that using a mixture of blast furnace and coke-oven gases, the blast-furnace gas being enriched by the coke-oven gas. The blast-furnace gas engine was thermally very efficient, but was it economically the most efficient engine? In using low-grade gas, one had a large number of much more expensive engines, and from the commercial point of view it might pay better to use a smaller engine and enriched gas.

Mr. H. M. Ridge noticed that great stress was laid by the authors on the question of gas cleaning, and the electrostatic cleaning of gas was put forward as being the only workable means. Experiments were being made in other directions, and he thought that soon a very much cheaper form of apparatus would be available for the efficient cleaning of gas. Sir Robert Hadfield and Mr. Sarjant had emphasised the great lack of data available in connection with open-hearth furnaces, and he agreed with them. It was, however, known that the two largest sources for loss of heat were the heat units contained in the slag and, above all, in the waste gases. Up to now, there had been found no means of recovering the heat units from the slag. The best figure giving a guide to the proportion of heat lost in the waste gases from the open-hearth furnace, was in the region of 25 per cent. Here Mr. Ridge exhibited a table giving the effect of the use of various volumes of recording air, on the basis of pure carbon as fuel, and from his figures, he thought the loss, instead of working out at about 25 per cent., would be more in the region of 100 per cent. Mr. Bagley had given 600 deg. C. as the temperature of the waste gases, going through the chimney. With 25 per cent. excess of air, it was found by Mr. Ridge's table that 27 per cent. of the total heat units (on the basis of pure carbon) was sent away, but that was not really the maximum figure, for bituminous coal was used and not pure carbon, and when the producers were steam blown, there occurred a certain amount of undecomposed water, and the figure 27 had to be increased by about one-quarter that amount. When that was found to take place, he did not think it mattered much what the radiation heat loss of the furnace was; it was much smaller, and there had to be a certain heat radiation from the furnace to cool the brick wall. The one place where heat units could be saved was in the waste gases. Some records he had showed that the waste gases were leaving at 800 degs. C. He thought it undesirable to pass gases at 800 deg. C., or even 600 degs. C., to waste-heat boilers, as the gases could be used more efficiently for heating the secondary air and the gas. This did not mean a radical alteration in the steel works; only a certain amount of additions to recover those heat units, which could be done with the existing plants. He had furnaces built during the war, where after heating the secondary air, he had been reducing the temperature of the waste gases to 270 deg. C. From a fuel consumption of 150 tons he had come down to 80 tons, due to that detail alone. This was not an isolated instance, he had obtained the same good results in six or eight other cases without any trouble, the plants working quite satisfactorily.

Mr. F. Foster said the 33 cwt. of total fuel mentioned by Professor Bone had practically been obtained in actual working by a German plant; the consumption was 1,847 tons, or 37 cwt. of coal to the steel works per ton of finished steel. The finished section was about 86 per cent. of the ingot, or on that basis a coal consumption of about 33 cwt. The iron in the ore was about 48 per cent. The coke per ton of pig 22·86 cwt. The air blown at 60 deg. F. 131,000 cub. ft. The gas given off 179,000 cub. ft. This proved that with certain qualities of ore the ideal could be attained. He did not agree entirely with Mr. Ridge in his statement of the low loss by radiation in open-hearth furnaces. He (the speaker) had found that there was sometimes a large loss by radiation. An important fuel economy could be reached by driving the furnaces hard, both the blast furnace and the steel furnace. Here, the blast furnace was not as a rule driven hard, and he thought that was largely due to the shape of the furnace. In the open-hearth furnace, a better furnace was required. Rapid melting could not be obtained without high temperatures. He did not think that so high an excess of air obtained as pointed out by Mr. Ridge. Mr. Ridge had suggested that the waste heat should not be used in boilers; that raised another question of furnace design which he could not enter into, but so long as there was waste heat, he (the speaker) thought it was desirable to utilise it in waste heat boilers. He could say there could be no hesitation to-day on the sense of reliability of the gas engine; the gas engine had to be built by a firm who understood the engineering side, the design side and the making of it. The workmanship in itself was sufficient to spoil any gas engine if it was of a defective order. The utilisation of the waste heat from gas engines was not a new problem and it added to the economy of a plant, to the extent of probably 12½ per cent. It was also possible to use some of the jacket water. It might pay in some cases to run the molten slag from a blast furnace through a relatively fine sieve and let it descend as rain of molten slag against a rapid up-current of air to heat the latter; the suggestion, however, was not a practical one at the present time, but something might be done on these lines. It was not satisfactory to raise steam by running the hot slag into water. In regard to the week-end gas, this could be sold in the shape of current to public companies, or stored in batteries; this latter point, however, also required going into in greater detail. He thought economy in the future consisted, as Professor Bone had suggested, in knowing what one was doing, in putting in position a responsible agent, in the proper arrangement of a plant, and in hard driving. The time element was as important as any other.

After a few remarks by Mr. T. H. Bailey on the human element, labour, wages and shorter hours, Mr. W. H. Patchell said he served on the Committee of the British Association with Professor Bone and Sir Robert Hadfield, and the Committee had considered the question of the disposition of the paper. It was a matter of congratulation that Sir Robert was able to get it brought before the Institute,

as the discussion would be more useful than the one at Bournemouth the previous week. Professor Bone and Mr. Cosmo Johns had spoken of exhaust boilers as if these had not been tried. Friends of his (the speaker's) had 3,000 h.p. of gas engines and internal combustion engines—nearly all gas engines—with exhaust boilers behind them, and were getting 2·45 lb. of steam, from and at 212 deg. per brake horse-power, with an average load on the gas engine of 75 per cent. to 77 per cent. Now, the thermal equivalent of a brake horse-power was 2,545 thermal units; the thermal equivalent of 1 lb. evaporated from and at 212 deg. was 2,380. He thought they got pretty well the thermal equivalent of a brake horse-power for the waste gases per brake horse-power. In regard to Mr. Lamberton's remarks as to costs, although costs had risen enormously, so in the same way had the cost of fuel. He was responsible for a large plant in which the pre-war cost of the fuel proposed to be used was 17*s.* 6*d.* per ton, and he presumed there would be about 7 per cent. of dirt in it. At the present time they were glad to get fuel at 37*s.* 6*d.* per ton with 30 per cent. to 50 per cent. of ash in it. These figures had to be remembered as well as capital costs. He was familiar with what had been done in gas engines in Saarbrücken and other places, and remembered in the early days being impressed with the number of cracked cylinders lying about there. Those engines were put in by men having a great deal of waste fuel, and instead of wasting that fuel they saved it and spent money on gaining gas engine experience. That had paid them. At Bargoed, in this country, he had been told that the engines had paid well. The multi-cylinder engine had been developed in this country and he felt confident that the large engine would still have its day. It had not been developed here as it should have been. Mr. Talbot had referred to linking up. There were at present large linking-up schemes before the country; they were told that the whole country was to be electrified. The whole thing was sanitary, but would it be economical? Mr. Talbot was responsible for large plants in a district where inter-connecting had been carried out to a very great extent, and they all admired the commercial acumen with which the North-East Coast electrification had been developed. The company had settled on the ideal district and had inter-connected the different industries there. Who could say that what had been successful in the North-East would also be successful elsewhere? A previous speaker had referred to battery storage over week-ends; in one large German colliery storage batteries were put down but were thrown out after a very short time and replaced by a fly-wheel, and he (the speaker) did not think a storage battery could be conscientiously recommended to the iron and steel trade to take care of week ends. In regard to the Steere Engineering Company's charts distributed by Sir Robert Hadfield, he (the speaker) said that possibly some instrument had been devised by the Steere Company which would define quantitatively what they had been doing for years qualitatively. Such a test as that described was taken by some people several times a day. One difficulty that did not arise was the question of colour of the tar and, as present applied, it was impossible to get two men to repeat exactly the same result. He remembered years ago a gas cleaner in which a piece of special blotting paper was held over the jet and he presumed the Steere Engineering Company's apparatus was something on those lines.

Mr. E. Bury, speaking on Mr. Cosmo Johns' paper, expressed his appreciation of it. The views therein expressed on the application of waste gas for the development of power and heat required for the conversion of pig iron into finished steel were generally in agreement with the line of development at Skinningrove, where owing to the distance from the coalfields, fuel saving had always been a matter of very great importance. Therefore, Skinningrove had decided to attempt to make their works self-contained from the fuel standpoint, namely, to obtain surplus coke over bases which together with the blast furnace gases would suffice for the power and heat required to convert their entire make of iron into finished steel. They, therefore, decided to adopt regenerative coke ovens, an entirely gas engine driven power station, electric transmission throughout the works, and soaking pits fired with blast-furnace and coke-oven gas. Their first gas blowing engine, the last stage of the final development of the blast furnace gas utilisation, would be started shortly. Their steps towards fuel economy, had therefore up till now laid directly or indirectly in the utilisation of the coke oven gas only; with that gas alone they had been able to provide sufficient power for the whole of the works, in addition to heating and rolling their make of ingots which had roughly been equal to half their make of pig-iron. They were completing the erection of an electrostatic gas cleaning plant. On their programme being completed, they calculated that their fuel policy would be self-contained as between the coke ovens and the blast furnaces and the finished steel. But in the execution of this policy there was very little margin, and they did not agree with some of the estimates of available gas supply which had been made of recent years; it was only by the most careful and efficent supervision and thoroughly good working between the departments that their policy might be rendered successful. Large savings in fuel might be effected, but the calorimeter and pyrometer had to be part of the normal works equipment. Mr. Bury then put in a table showing the Skinningrove fuel balance. He emphasised that to carry out the self-contained fuel policy and replace the gas producers at an open-hearth plant, the coke must be made at the steel works.

Mr. L. C. Harvey said the fuel wastage in this country was colossal and reprehensible; at least 30 per cent. of the fuel now used could be readily saved. Professor Bone's report contained figures which he had been trying to get for a long time. In America, every works of importance had its efficiency engineer and fuel consumption figures could be obtained from him. It was stated before the Coal Commission that for producing one ton of steel in this country, four tons of coal were used; but Professor Bone in his figures for a Lincolnshire plant had given a fuel consumption of from 50 cwt. to 55 cwt. per ton of finished sections. It was rather unfortunate that the members could not have a certain defined section, and the figure of consumption brought down to that.

Mr. R. C. Harding, who followed, and read a long contribution, said much of the authors' paper was in the economical use of blast furnace gas, and rightly so since more than half the calorific value of the coke charged in the furnace appeared in the gas given off at the furnace top. He had been in the Saar district, and the large surplus of blast furnace gas was very apparent there. Economy in its use had received great attention, and the result was seen in the great power stations of gas driven engines at every works.

Mr. J. A. C. Edmiston stated he was wholly in agreement with the concluding remarks of Professor Bone's report. Few large industrial firms paid much attention to the economical use of their fuel and there was much waste. If the use of fuel in all industrial concerns were put in charge of a competent chemist, or "Fuel Technologist" having good theoretical and practical knowledge, the saving would startle the management of those firms. The methods proposed in the report were quite satisfactory, but no information was given as to the conditions to be obtained in works having no blast furnaces and coke ovens, except in the utilisation of waste gases from steel furnaces. If the Fuel Technologist explained the principles of scientific working of a gas producing plant to the foremen in charge and also to the gas men, better results would be obtained than now. The exact use and purpose of each instrument used should be explained to them. In that way a good gas would be obtained. The higher the efficiency of the gas production plant, the higher would be the efficiency of the furnace. It would be interesting to know the quantity and pressure of steam used in gasifying 1 cwt. of fuel in fan blown gas producers, and the saving, if any, over the steam jet blown producers. He thought that the combustion of fuel should be considered more from a physical than from a chemical standpoint as at present.

Mr. H. Crowe said emphasis had been laid on the rolling off of ingots in Germany to save the heating up, but he thought that practice was not so good as the English. In regard to the big German cogging mills, the general trend of opinion was in favour of the steam drive, but in his opinion electricity was more suitable in high-powered mills, where the passes were short and frequent. Electricity was more suitable for cogging, and least suitable for finishing. If electricity was used it should be used right through, as the two forms of power could not be mixed. He did not agree that a steam engine was preferable for the cogging; the reverse was the case. Steam was preferable for finishing. He thought a positive piston blower was better for a blast furnace than a turbo-blower; one knew what would happen with a piston, but that was not the case with a turbo-blower. The question of steam and gas in connection with a gas producer was an important point; they had thought of it at Skinningrove but had not done anything with it. He suggested that one could put blast furnace gas in the producer instead of steam; this would keep the heat down in the producer and a gas would be obtained very low in hydrogen and very high in CO, an ideal gas for open-hearth work. Some of the gas engines at Skinningrove had been running for nine or ten years and worked well. He agreed that there should be scientific control of fuel at the soaking pits, but there should also be control of the waste on the ingots, otherwise much steel might be burnt away; what was earned on the gas might be much more than lost on the steel. A good practical heater was required at the soaking pit.

On the authors stating that they would reply to the discussion in writing, the Chairman said he had never attended a more interesting or better attended meeting. He asked the members to accord a cordial vote of thanks to the authors, the resolution being carried by acclamation.

The Blacksmiths' Company.

It was announced in the course of Thursday's meeting that the annual award of the freedom of this company and a gold medal—referred to in the last spring meeting of the Institute—would be made for the first time at the May meeting of next year.

(To be continued.)

INDUSTRIAL NOTES.

The Ministry of Labour dealing with the labour market state, in *The Labour Gazette*, that apart from the effects of the Yorkshire coal dispute, employment generally showed an improvement in August. The number of out-of-work donation policies lodged at the end of each of the last six weeks for which statistics are available was as follows:—

July 25	540,884
August 1	553,482
August 8	536,986
August 15	530,523
August 22	510,075
August 29	478,084

Work in the Yorkshire collieries had not been fully resumed at the end of August, and the pig-iron, iron and steel, glass, textile and some other industries in Yorkshire continued to be effected by fuel shortage.

Increases in wages which came into operation in August were obtained by over 359,000 workpeople and decreases in hours affected about 65,000 workpeople. At September 1 the general level of retail prices of food and other items entering into the cost of living was about the same as a month earlier, viz., 115 per cent. above the pre-war level.

The 478,084 out-of-work donation policies lodged at August 29 were distributed as follows: Civilians—men 83,035, boys 5,006, women 49,038, girls 4,053; demobilised—men 334,925, women 2,027. Of the total number of civilians 40,341 were in receipt of the reduced donation paid after the expiry of the first period of 13 weeks' unemployment.

The number of men on the live registers of the Employment Exchanges at September 5 was 433,591, or a decrease of 83,852 at August 1; and the number of women was 105,565, or a decrease of 43,899 on the total at August 1. The number of vacancies unfilled on September 5 was 38,806 for men and 43,796 for women, the corresponding figures for August 1 being 40,004 and 47,936.

Trade unions with a net membership of 1,439,731, excluding those serving with H.M. Forces, reported 2·2 per cent. of their members as unemployed at the end of August, as compared with 2 per cent. at the end of July and 0·5 per cent. a year ago. The slight

increase reported this month is mainly due to unemployment in the textile bleaching, dyeing, printing and finishing trades.

The number of workpeople employed at coal mines included in the returns was slightly greater in the week ended August 23 than a month earlier, and over 20 per cent. greater than a year ago. The average number of days worked by the mines during the week was 5·70, as compared with 5·75 in August, 1918. These figures are exclusive of Yorkshire, where employment was still dislocated by the strike.

At iron and shale mines and at quarries, employment continued good on the whole, but at tin mines it remained quiet; with lead miners employment varied greatly in different localities.

The pig-iron industry continued to be affected generally by the shortage of fuel, and although the number of furnaces in blast was 235 at the end of August, as compared with 231 at the end of July, it was much below that for June, when 270 furnaces were in blast. At iron and steel works employment improved, and the number of workpeople employed by firms making returns in the week ended August 23 was 9 per cent. greater than a month earlier, though 2 per cent. less than a year ago. The average number of shifts worked in the week was 5·50, as compared with 5·39 a month earlier, and 5·70 in the corresponding week in 1918. In the engineering trade employment continued fairly good and showed some improvement, and in the shipbuilding trade it remained good on the whole, though towards the end of the month it was slightly affected by the cancellation of Admiralty orders. Tin-plate workers were well employed, though some mills were idle owing to drought. In the other metal trades employment continued fairly good.

In the cotton trade employment improved further and additional machinery was started, but shortage of coal was frequently reported and resulted in some short time. The woollen and worsted trades and the textile bleaching, dyeing, printing and finishing trades were seriously affected by the Yorkshire coal strike, and many mills were closed down for some time in August. Employment in the brick, cement and pottery trades was good in August, though a scarcity of fuel was frequently reported, but the glass trade was seriously affected by the coal strike in Yorkshire. In the building, woodworking and furnishing trades employment was good on the whole. Employment in the paper trade continued to improve and was good generally. With dock and riverside labourers employment was fairly good. The supply of seamen was, on the whole, in excess of the demand.

The changes in rates of wages reported as having come into operation in August resulted in an increase of about 85,000*l.* in the weekly wages of over 350,000 workpeople. The principal increases affected workpeople in the carting, baking and flour-milling industries, and iron puddlers and millmen in the Midlands. Changes in hours of labour during August affected about 65,000 workpeople, whose recognised working time was reduced by an average of nearly 7 hours per week; the changes affected chiefly workpeople in the paper-making and baking industries.

Sir G. B. Hunter, of Messrs. Swan, Hunter and Wigham Richardson, of Wallsend-on-Tyne, in a letter to the press, writes as follows: "Never before has there been half so much need of increased output, increased exports and the increased production of wealth. We are living on credit and our credit is being exhausted. Our capital is being rapidly conscripted, and at the present rate of waste it will not last many years. It is well known that we are spending too much and working too little. It is practically certain that we are in imminent danger of such a partial or complete collapse of our financial and industrial prosperity as will cause widespread unemployment. Yet it is a fact that we are now living in a fool's paradise, and doing less work and producing wealth more slowly than before the war. The people have been, and are being, encouraged to believe that without increased exertion they can build a better England and be more prosperous than before the war. The cost of living has become more and more oppressive, not so much by profiteering as by under-production, excessive consumption and high wages. Yet shorter and still shorter hours of work and higher and still higher wages (not only for the lower paid but for the highest paid workers) are being demanded.

"Yet at this time our Government has chosen to introduce a Bill to limit under penalties the increased production of wealth by depriving men who are now free and perfectly able and willing to protect themselves of their right to work more than 48 hours a week. Such a proposal would be at any time economically unsound and suicidal and a gross infringement of individual liberty. There never was a time when it was less needed. There never will be a time when it could be so harmful as now. It should be added that this Bill is not (as is asserted) a measure that has been agreed or approved by properly accredited representatives of labour and capital and, what is quite equally important, of the consumer. Its effects have not been discussed and considered with any approach to the care which their importance demands.

"I gladly acknowledge that our trade union leaders recognise the danger and are now advising and warning their members that the production of wealth must be increased if their prosperity is to be maintained. We gladly recognise also that very many of the members of trade unions are doing their best by precept and example to discourage slackness and increase output. . . . It is a fact, nevertheless, that the average output of work in Great Britain through excessive holidays, short time-keeping, and the lack of effort to produce wealth, and, it must be added, even by a widespread desire (due to ignorance) to restrict production, is not much more than half of what it might be and should be. It is quite futile for anyone to deny that there is a considerable amount of voluntary limitation and slackness.

"If I assert that the workers do now receive a fair share of the work they produce they will probably not agree (and I have not space to prove it), but it is none the less broadly and demonstratively true. This at least will be accepted by the thoughtful labour leader and trade unionist, that, however the profit may be divided, nothing can prevent the workers from greatly benefiting by increased production. They cannot fail to benefit by it, and they cannot fail to benefit much more than employers or capitalists."

At the concluding meeting of the conference of the newly-formed Union of Postal Workers, at the Central Hall, Westminster, last Saturday, a resolution was brought forward stating that the time had arrived for post office workers to defy the post office authorities in connection with restrictions placed upon them in regard to the exercise of political rights. It called upon members of the union openly to work for Labour Party candidates at the next general election. The proposal was opposed by Mr. Stuart Bunning, who said that if the resolution was passed any member could get up on a platform at a by-election and so behave himself that he would be dismissed by the Postmaster-General, and the union would have to keep him for life. After some discussion the resolution was shelved.

There is trouble in connection with the Scottish shale oil trade. The men are demanding such improved conditions as coal-mine workers have received under the Sankey award, but the operating companies contend that the extra charges would be such that the trade could not stand them. Various meetings of the workers were held during last week-end, and the men have declared a strike to begin to-morrow. In view of this, steps have been taken by the companies to close down their mines and works on Saturday.

It is estimated that about 10,000 men are involved, and that nearly a dozen villages, with a total population of over 50,000 people, will be affected.

The companies were recently formed into a combination known as the "Scottish Oils, Limited," and the ordinary shares of the separate concerns are held by the Anglo-Persian Oil Company, Limited, which now has a controlling interest in the English trade.

Within recent years the industry has had a hard struggle for existence, and has met with keen competition from American producers.

Much interest and a good deal of surprise was created early in the week by the somewhat theatrical announcement of a new railway crisis. The position, of course, is that under the terms of the settlement last February standard rates were to be worked out for all grades, but in any case every worker was to receive his full war wage until the end of this year. Under these circumstances and in view of the fact that the year still has three months to run there can be no good reason for a "crisis" developing at the present time. In the interview during which Mr. J. H. Thomas made the announcement on which the "crisis" was based, he stated that the Government's present proposals for new rates would result in some grades having to submit to a reduction on their present wages of as much as 14*s.* a week. The proposed rates, we take it, are still under discussion, and it is impossible to know in the absence of detailed information if such a reduction might or might not, in some grades, be justifiable. Mr. Thomas states that it was understood last February that in the working out of the standard rates all grading should be upwards. This may have been so, but any such understanding must have been a very illogical one. The working out of standard rates for all grades in such a complicated and vast business as that carried on by the railways is a matter that can only be properly done after the examination of an enormous mass of detail, and to enter on it with the understanding that everyone is to get a rise out of it is to stultify any logical outcome from the first. The situation has developed rapidly and an ultimatum was sent to the Government by the men on Wednesday, to the effect that unless a new wage offer was made by noon on Thursday a strike would be called on Friday. In reply to this it was announced late on Wednesday night that the Government would meet the railway leaders to again discuss the matter. This conference is proceeding as we go to press.

The strike of ironfounders which began last Saturday is likely to have a serious effect on the engineering industry generally if it continues for any length of time. Very many firms whose output involves the use of castings have already instructed their workpeople that they may have to close down certain departments. Three unions are concerned in the strike—the Ironfounders Society, the Amalgamated Society of Coreworkers, and the Iron and Steel Metal Dressers Society. The total membership is approximately 50,000. Briefly, the strike is for a rise of 15*s.* a week. The position of affairs is clearly given in a statement issued by the Ministry of Labour on the 23rd inst. The statement is as follows:—

"The trade unions concerned were parties to an agreement arrived at in February, 1917, with the Engineering Employers' Federation, whereby claims for alterations in wage rates in the engineering and foundry trades were to be made in the months of February, June and October, the awards of the Committee on Production, and subsequently of the Court of Arbitration, becoming operative in the months of April, August and December each year.

"Together with the other unions in the engineering and foundry trades, the three trade unions whose members are on strike were voluntarily parties to a claim made in accordance with this agreement in June last. The award made by the Court of Arbitration in July as a result of this claim became operative in August, and the employers are under a legal obligation to pay wages in accordance with that award until the normal period of four months elapses, *i.e.*, until December 1.

"The Ministry of Labour take the view that the trade unions are morally bound to observe the same conditions, and that they should wait until the ordinary time (October) before making any further claim for an alteration. It is for the trade unions to decide whether they will be parties to arbitration on the further claim, but the Ministry of Labour hold the view that while the employers are under a legal obligation to carry out the award of the Court of Arbitration, it is equally the duty of the trade unions concerned to accept the terms of the award for the period for which it is operative."

The unions state that they are at liberty to withdraw from the national agreement and have done so, after due notice.

The strike of steel workers in America is assuming important proportions, and it is variously reported that from 200,000 to 300,000 workers are out, the employees claiming the larger figures. The strike is concerned with the recognition of unions, shorter hours and higher wages. No sign of a settlement is yet in sight. The strike has unfortunately been attended by some of the warlike methods with which previous similar troubles in the United States have made one not unfamiliar.

In the trade returns for July, 1919, published by the Department of Statistics, imports amounted to 9,959,000*l.*, a decrease of 1,732,000*l.*; and exports (including re-exports) to 18,592,000*l.*, an increase of 5,027,000*l.*, as compared with the corresponding month of 1918. There was a decrease in the exports of food, drink and tobacco (mainly food-grains and tea) amounting to 2,347,000*l.*, but raw materials and articles mainly manufactured increased by 5,778,000*l.*, owing to larger exports of raw hides and skins, seeds and raw cotton. Articles, wholly or mainly manufactured rose by 645,000*l.* mainly on account of larger exports of tanned hides and skins, and cotton manufactures, including twist and yarn, notwithstanding smaller shipments of jute goods. During July of the pre-war year 1914, imports amounted to 9,335,000*l.* and exports (including re-exports) to 13,045,000*l.*

PYROMETRY IN THE STEEL WORKS.—The American Committee on Pyrometry have been experimenting at the Midvale steel works with an optical pyrometer sighted on the bottom of a closed tube of refractory material immersed in the bath. If a suitable material could be found for the tube, this method would give the temperature of the steel with great accuracy, but so far none of the materials tried have proved satisfactory. The Burgess method of taking a series of readings with an optical pyrometer of the temperature of a stream of molten steel poured from a hand ladle and calculating back to the moment of dipping the ladle, was found to be trustworthy within 10 deg. or 20 deg. C.

PORTABLE MILITARY BRIDGES.*

By Professor C. E. INGLIS (Major, R.E., O.B.E.).

THE paper which I have the honour to read to you to-day will deal mainly with the evolution of a type of military bridge which, on account of its portability and ease of construction, became in the later stages of the war the standard type for rapid advance work, capable in its various forms of carrying light and heavy military transport across clear spans up to 100 ft. and sometimes even more. The first example of the class of bridge under consideration came into existence in June, 1914, and its birth was brought about by the following circumstances: At Cambridge in pre-war days a flourishing

Fig. 1.

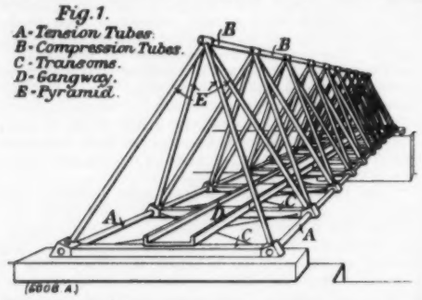
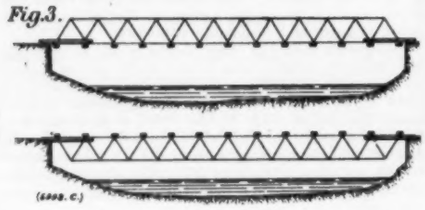


Fig. 3.



Officers' Training Corps had taken root, and one of its most vigorous branches was a Royal Engineer unit. Field days occupied a prominent part in our programme of activities, and on such occasions the task allotted to the Royal Engineer company was almost invariably the construction of a trestle bridge across the river Cam. More often than not, to our bitter disappointment, the battle was fought and won 'ere ever it reached the bridge we had constructed with so much care. This disappointment oft repeated had a damping effect on our military ardour, and enthusiasm for field days became more and more difficult to sustain.

It appeared to me that the solution of this difficulty was to be found in the provision of a light and mobile bridge capable of very rapid construction which would enable the sappers to co-operate in close touch with the infantry and thereby participate actively and intelligently in the progress of the battle.

After one or two abortive attempts a construction was achieved which apparently satisfied these conditions, and more by good luck than by prophetic insight the main characteristics of the design were such that they have survived almost unchanged during the process of evolution from the original light type down to the recent substantial constructions capable of carrying the heaviest military load, namely, a 40-ton tank.

The general nature of this light type bridge is diagrammatically represented by Fig. 1. Its anatomy consists of a number of four-sided pyramids. Their bases joined together form the roadway, and a series of struts coupling together the apexes of successive pyramids constitute the top compression boom of the bridge. The main members are steel tubes attached at their ends (in a manner which will be explained subsequently) to cast steel junction boxes.

The bays out of which the bridge is formed are all dentical, and each bay consists of the following parts:—

Two horizontal tension tubes.
One horizontal compression tube.
One cross-beam or transom.
One pyramid.
One gangboard.

The four legs of the pyramid are permanently hinged to the top junction box, and they fold together forming a single unit convenient for transport.

The square base to which the power ends of the pyramid legs are attached is braced by diagonal rods which can be strained tight by means of turnbuckles. These diagonal bracing rods are permanently hinged to the transom and form an integral part of that unit.

The roadway in its earliest and simplest form consisted of a single central line of gangboards with their ends resting freely on the transoms and of just sufficient width to allow the passage of infantry marching in single file. Later on a more commodious decking was provided which enabled horses to be led across the bridge. The base of the pyramid is a square of 8 ft. side, and the vertical height of the compression tube above the tension tubes is also 8 ft.

The strength of the bridge is calculated to carry infantry in single file crowded closely together over a clear span of 96 ft. Owing to the fact that the stresses in the tubes are strictly axial the rigidity is quite remarkable for so light a structure. The maximum deflection for a span of 96 ft. fully loaded does not exceed 2 in., and the triangular section of the girder renders it almost equally stiff in a lateral direction.

The weight of a bay, including the footway, is 510 lb., so that the weight of a 96-ft. span is about 2¼ tons. These weights and dimensions do not refer to the first experimental bridge made at Cambridge.

At the request of the Royal Engineer authorities at Chatham this same bridge was sent to them for inspection in October, 1914. As the result of trials it was viewed with favour, but quite justly criticised as being insufficiently robust to withstand the vicissitudes of real military service. Nevertheless, the general concensus of opinion was so friendly and encouraging that the construction of a strengthened and improved type was felt to be justifiable and any difficulty of finance was unexpectedly removed by Messrs. Dick Kerr and Co. who offered most generously to make a sample free of cost at their Kilmarnock works.

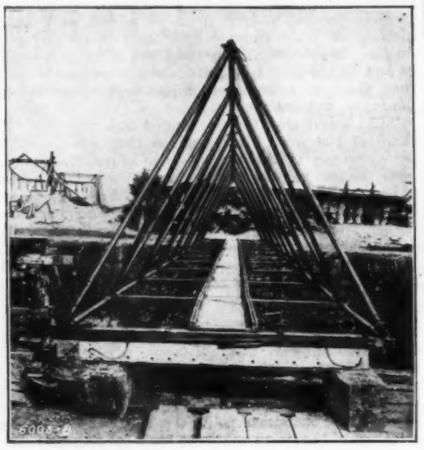


FIG. 2. EXPERIMENTAL BRIDGE.

Fig. 2 shows this No. 2 experimental bridge, and the dimensions and weights previously stated relate to this example. This was appreciably more commodious and substantial than its predecessor, and the camber which was a noticeable feature in No. 1 bridge has in this case entirely disappeared. This was done in order to be able to use the bridge inverted in the manner indicated by Fig. 3.

Thus inverted the construction becomes a deck bridge, suitable for a class of light wheeled traffic which could not pass through the triangular gauge associated with the bridge when used in its normal "through" type condition.

When used upside down the bridge is supported on substantial projecting horns which are bolted to the two end transoms. In this form the bridge also provides a convenient arrangement of false work for the erection and launching of heavy girders across a gap. Fig. 4 shows the various component parts which go to form a complete bay. This No. 2 bridge was completed in the summer of 1915. It was thoroughly tested at Chatham, and as the result of a favourable report 1,000 ft. was ordered for use by our armies overseas, and the existing sample was shipped to France for inspection and tests.

In the culminating trial which took place in the presence of a number of bridge specialists and other high military authorities, the bridge material was packed into two lorries and taken to the banks of a canal. There the parts were unloaded, and after they had been laid out, the order to construct bridge was given. Measured from that moment to the instant when the bridge was across the canal ready for traffic the time was just 11 minutes, 20 men being employed in the erection.

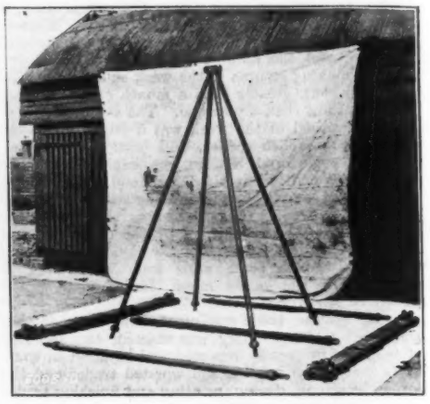
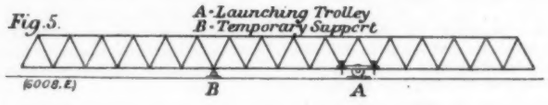


FIG. 4. COMPONENT PARTS OF A BAY.

Fig. 5.



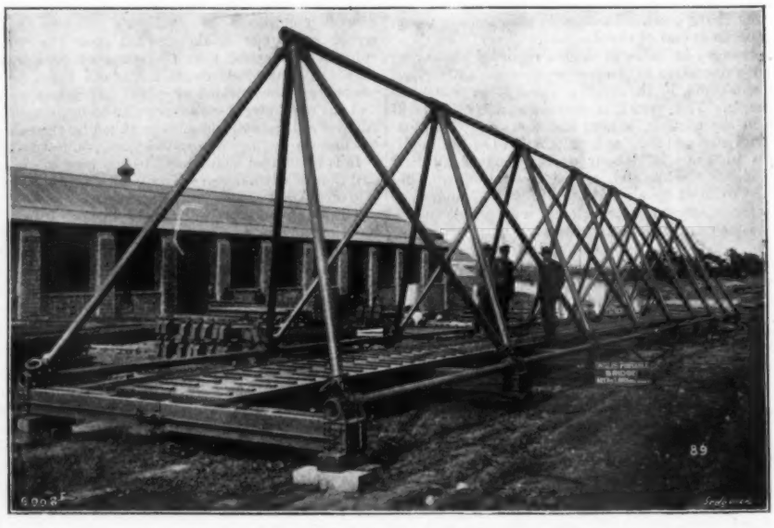


FIG. 6. ENLARGED TYPE OF BRIDGE.

From an account given in an American journal which described building operations at the American Bridging School in France, it appears that this time has been considerably reduced in that they claim there to have performed an almost similar feat in 7¼ minutes, 4¼ minutes being spent in assembling 104 ft. of bridge and 3 minutes in launching and completing it ready for traffic. This rapidity of construction can be attributed in part to the simple but efficient jointing device and in part to the method of launching the bridge across the gap. This method can be understood by reference to Fig. 5.

The first bay is erected on a strong two-wheeled trolley. A long arm sufficient for the gap which has to be bridged is built out on one side of the trolley and a shorter arm or tail which serves the purpose of a partial counterweight is built out in the opposite direction. The erection, if possible, is effected along a line parallel to the banks of the gap, as, for instance, along the towpath of a river or canal.

* Paper read before Section G of the British Association, at Bournemouth, September 10, 1919.

Additional counterweight, generally in the form of a human load, is added to the end bay of the tail until the whole construction see-saws about the axle of the trolley. The complete structure is then swung round, the two independent wheels of the trolley acting in a manner similar to the rollers of a turn-table. When the outer end reaches the opposite bank, the counterbalance tail is dismantled and the trolley removed. The decking having been placed in position previously to the process of swinging, the bridge is then ready for traffic. It may happen that the configuration of the banks or the presence of obstacles such as trees and telegraph poles precludes the possibility of swinging. In this case there remains the alternative of building of gangboards, flanked on either sides by rolled steel joists laid on their sides. The rolled steel joists laid thus formed strong troughs in which the wheels of the military vehicles could run, and this arrangement was possible owing to the fortunate circumstance that the various vehicles which had to be catered for were almost identical in the matter of their wheel tracks.

Before this 12-ft. type had come forward in any quantity the question of a rapid bridge for motor lorries and heavy guns was raised, and this demand was in the first instance met by the twin-bridge construction shown in Fig. 7.

In this design a central roadway, 10 ft. between kerbs is supported on substantial trussed beams hung from the

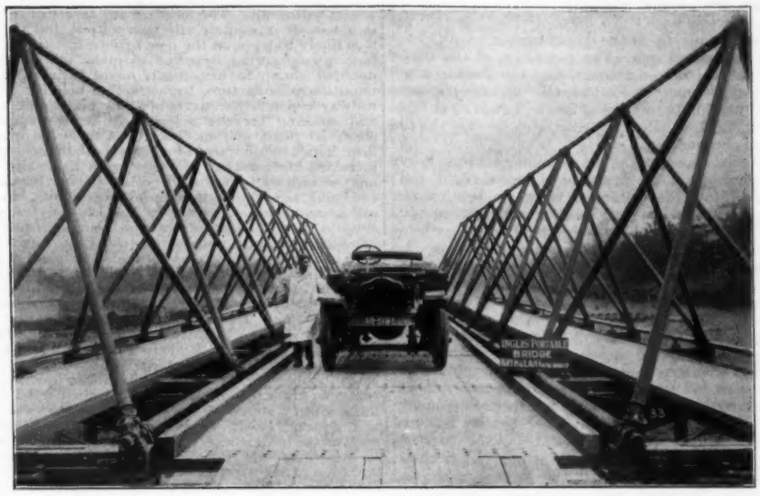


FIG. 7. TWIN-BRIDGE FOR HEAVY TRAFFIC.

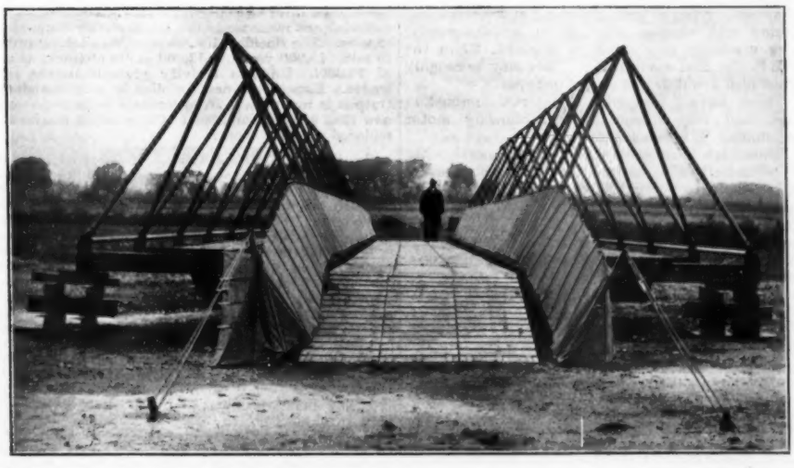


FIG. 8. TWIN-BRIDGE FOR LIGHT TRAFFIC.

the bridge at right angles to the banks of the gap and pushing it bodily forward on its trolley like a ship's gangway.

With a bridge arm of 104 ft. extending out as a cantilever from the trolley, the tube stresses are considerable, and the factor of safety is less in this condition than when the bridge is in position fully loaded. Moreover, the bottom horizontal tubes which are normally in tension have during this stage to act as compression members, and this consideration is the main factor which governs the design of these so-called tension tubes.

After the trial of the light bridge, which took place in December, 1915, the evolution of this type of tubular construction was rapid. Branches of the service other than the infantry immediately claimed consideration, and to meet the demands of the gunners and the Army Service Corps in particular an enlarged type was produced. Fig. 6 illustrates this bridge.

The bays in this case were 12 ft. wide and 12 ft. long, and the pyramids were 12 ft. high. In this form the bridge could carry field guns and general service wagons crowded as close as possible on a 96-ft. clear span, the safe distributed dead load for this span being 24 tons. With the exception of the decking it was practically a copy of its predecessor, the light type bridge. The decking in this case consisted of two longitudinal lines centres of the transoms of the two parallel bridges; wheeled traffic passes along the central roadway and the supporting bridges form side tracks for pedestrians. A similar twin construction was adopted in connection with the light bridging material. An example of this type of bridge is shown in Fig. 8. This light twin bridge found favour with the cavalry and survived without further modification to the end of the war.

The large twin bridge, on the other hand, was soon superseded, its chief advantage lay in the fact that it utilised existing material, but it possessed the serious drawback of being uncomfortably wide compared with most road-bridge abutments and the large number of different parts required for its construction was also a disadvantage.

(To be continued.)

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.—A plenary meeting of the International Electrotechnical Commission will be held in London on October 20, 21, 22 and 23. This is the first plenary meeting since the outbreak of war, and important questions in regard to the future work of the Commission will come forward for decision. It is confidently expected that 40 to 50 delegates will be present, representing 16 to 18 countries.

"THE BUILDING OF AIRSHIPS."

TO THE EDITOR OF ENGINEERING.

SIR,—I notice in your issue of the 12th inst. that Mr. Lightfoot has again written with the object of proving that it is impossible that airships can be used commercially in the future. The fact that there was a successful commercial airship company in the past (Deutsche Luftschiffahrt Aktien Gesellschaft, which carried 17,000 passengers without accident), does much to shake one's confidence in his arguments, which receive yet a further shock from the fact that there is one post-war commercial Zeppelin, the Bodensee, operating at the present time.

To turn for a moment from matters of fact to questions of opinion, Mr. Lightfoot's view, since it is opposed to that expressed by both Sir Charles Parsons and Professor J. E. Petavel in their addresses to the British Association, appears to require a certain amount of confirmation before it can carry conviction.

I notice that Mr. Lightfoot refutes several of my statements, but while maintaining their correctness, I do not propose to weary you by argument in their support; however, I would point out that "mast mooring" *does* allow of the mooring out of an airship without its being "landed" first (a fact which can be substantiated by application to Messrs. Vickers, Limited, who are the owners of patents in connection with "mast mooring" of rigid airships), consequently an enormous reduction does take place on what Mr. Lightfoot calls the "normal strength of the landing party."

Surely it cannot be taken as any argument that a reduction in the Government airship programme is proof of the absence of airship *commercial* utility? Would it not have been perhaps an even better argument to have said in the early days of motor road transport that the fact that a horse 'bus company in financial difficulties didn't buy motor 'buses proved that the latter were without commercial utility.

In conclusion, does not the question of the commercial future of airships depend on what the public is prepared to pay for high-speed long-distance transportation over the sea, and on what volume of support it is prepared to give such transportation? Until this is settled by practical trial there can be no solution to the controversy which Mr. Lightfoot has raised.

I am, Sir, yours faithfully,

"WINCO."

Godesberg, near Bonn, September 15, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—As an engineering draftsman (British) many years resident in the United States of America, I was pleased to read in the papers here that the British Government had stopped work on the huge dirigibles that are now being constructed. It was a very wise move, and the men can be employed on far more useful work. Britain has shown the world that she leads in aeronautics, so let "Go easy" be the watchword from now on, in that particular line.

The idea of building an airship as big as an ocean liner, to carry a truck-load of goods across the ocean is a poor business proposition. Far better put the money and energy into a 20,000-ton tramp steamer that will carry a real cargo, even if it does take a little longer to cross the ocean.

From my observation in this country, the two industries which are in a large measure to blame for the high cost of living here are the motor car and aeroplane industries, for the simple reason that they are producing luxuries and not necessities, and employing hundreds of thousands of people who would otherwise be producing really useful goods and food products. I would say "Let America have the auto industry, also the aeroplane industry."

They are not fundamentals, and I believe we were happier and healthier when we had nothing better than a bicycle to get around with. Speed is not everything.

Britain has often been sneered at for being conservative, and slow going, but these are the very qualities, combined with a few others, which made it possible for such a small country to be the greatest single unit of power in the world.

We are living too fast for comfort these days. Let England concentrate on cargo boats, coal production, cottons and woollens, machinery, iron and steel, and last, but not least, agriculture, the things that really count, and just keep a "weather eye" on the developments of the "speed stuff" in other countries, and she will come to the top without knowing it.

Yours faithfully,

D. LLEWELYN DAVIES.

400, Tennyson Avenue, Syracuse, N.Y., U.S.A.

OIL AND FAT INDUSTRIES AT ESBJERG, DENMARK.—From a United States Commercial Report of June last we see that a small company for the production of edible bone fat, meat extract and bone meal was established at Esbjerg in 1916. Esbjerg is a port on the West Coast of Jutland and was, before the war, in regular steamer connection with Harwich. The company was to deal with 50 tons of fresh bones per month; the bones are steamed to extract the fat and then ground, the meal obtained being utilised as cattle food or as manure. The bone fat is sold in the district; some jelly settled on the fat was for some time sold to Germany; a stock of 50,000 kg. is said to have recently accumulated, however. This company has a capital of only 2,500*l*. A large company, the Danske Oliemoller Saebe Fabriken has, in the same place, spent 200,000*l*. on a plant for extracting oils from copra, saga beans, cotton seeds and ground nuts; the materials are extracted with benzene, but oil presses are being installed; a refinery is to be added to the plant.

THE INSTITUTE OF METALS.

THE autumn meeting of this Institute—the first London technical society to hold its autumn meeting outside London since hostilities ceased—took place last Wednesday and yesterday in the Mappin Hall of Sheffield University. The President, Professor H. C. H. Carpenter, M.A., was in the chair. An influential local reception committee had been formed, including many well-known gentlemen in the Sheffield industries and under the chairmanship of Dr. R. S. Hutten, member of council of the Institute. Mr. G. Bernard Brook, Professor at the University, was the honorary secretary. The local reception committee had offices at the University.

On the members assembling at the Mappin Hall, on Wednesday morning, the 24th inst., after inspection of the University rooms and laboratories, they were cordially welcomed by the Vice-Chancellor of the University, Professor W. Ripper, and the meeting proceeded to the reading and disussion of the following papers on the programme:—

"Season Cracking of Brass," by Dr. W. Hatfield and Captain G. L. Thirkell, B.Sc.; "The Ternary Alloys of Tin-Antimony-Arsenic," by Dr. Stead, F.R.S.; "The Properties of Standard or Sterling Silver, with Notes on its Manufacture," by Mr. E. A. Smith and Mr. H. Turner; "Note on Graphite and Oxide Inclusions in Nickel Silver," by Dr. F. C. Thompson, B.Sc.; "Observations on a Typical Bearing Metal," by Miss E. Fry and Dr. W. Rosenhain, F.R.S.; "Some Notes on the Constitution and Metallurgy of Britannia-Metal," by Dr. F. C. Thompson, B.Sc., and Mr. F. Orme, M.Met.

At the meeting the President announced that the President for the ensuing year was Eng.Vice-Admiral Sir George G. Goodwin, K.C.B., Engineer-in-Chief to the Fleet. Following this, the Master Cutler, Sir Albert Bingham, entertained the members and their ladies to lunch in the Cutlers' Hall, Church-street, and excursions and visits to alternative works were made in the afternoon. In the evening, a reception at the Town Hall was held by the Lord Mayor.

On Thursday morning, the remaining papers on the programme, "Second Beilby Report on the Solidification of Metals from the Liquid State," by Professor C. H. Desch, D.Sc., Ph.D.; "Moulding Sands for Non-Ferrous Foundry Work," by Mr. P. G. H. Boswell, O.B.E.; "Note on the Micro-Mechanism of the Ageing of Duralumin," by Dr. Fay Jeffries; "The Early History of Electro-Silver Plating," by Mr. R. E. Leader, B.A., were dealt with, and lunch was served to the members in the different works they had elected to visit.

On this occasion, the Institute issued a very neat illustrated booklet—giving the names of the members of the reception committee, those of the members attending the meetings, the programme, information on the University, brief descriptions of the places and works visited, and a street plan of Sheffield.

We shall deal with the proceedings at the meeting in forthcoming issues.

A very interesting addition to the programme consisted in a cinematograph display of brass-melting in the electric furnace, shown before the papers were read and discussed, each day.

THE TRACTOR TRIALS AT LINCOLN.

THE trials and exhibition of agricultural tractors organised by the Agricultural Section of the Society of Motor Manufacturers and Traders, Limited, near Lincoln, commenced on Monday last. The tests, which include ploughing and cultivating on light and heavy land, threshing and hauling, are admirably arranged. When the results are available they will be highly instructive and will carry out the intention of the organisers to provide a really useful help to intending purchasers in the selection of the most useful machine for their purpose. No attempt is being made to give prizes or arrange the machines in order of merit. Careful measurements are being made and the performances of the machines recorded; these will be published later. The entries are very representative, and include most of the tractors on the market. They will all be hard at work and compared under the same conditions on various classes of soil and on different jobs.

Monday and Tuesday were devoted to measuring the draw-bar pull of the various machines entered. Each tractor was hitched to a specially constructed trailer loaded with pig-iron, and fitted with screw-on brakes. It carried two observers, a recording dynamometer specially made and calibrated by the National Physical Laboratory at Teddington, and a speedometer. One observer controlled the brakes and kept the speed of the vehicle constant, and the other watched and took care of the recording dynamometer. The weather conditions were very suitable. Monday morning a slight rain fell, but a strong wind soon dried up the surface of the ground, and the tractors were able to work under favourable conditions. A heavy rain fell the whole of Monday night, but cleared off in the morning, and the ground was still in good condition for conducting the tests. No data of draw-bar pull are at present available, as the dynamometer records have yet to be worked out. The resistance of the trailer was adjusted to the maximum that the tractor would pull without slipping its road wheels. In a few instances the pull was limited by the adhesion, but in most cases this was ample to allow the tractor to develop the full power of the engine.

On Wednesday morning the ploughing trials on heavy land were held; on Thursday those on light soil; to-day, Friday, the cultivator trials are being made. During these three days threshing and hauling tests were arranged, a number of threshing machines being provided, and also hauling tests, which took place on a steep hill, with a loose surface, in the vicinity. The observation of the trials has been arranged on somewhat similar lines to those adopted by the society in their motor-car trials. Each entrant sends one observer with each machine, and this observer watches the performance of some other entrant's machine. A number of the farmers in the vicinity have volunteered to form a second set of observers, so that each test will be observed from an engineer's and farmer's point of view. Judges have been appointed by the National Farmers' Union. They are aided by the society's technical adviser, Mr. G. W. Watson, M.I.Mech.E., M.I.A.E., who has made all the arrangements and personally conducted and supervised the various mechanical tests.

Thirty-six different types of machines have entered and 53 machines are actually taking part in the trials, as many of the competitors have sent more than one machine of a type, so that ploughing and cultivating, threshing and hauling may go on simultaneously. Fifteen machines were made in England, 20 in the United States, and one in Italy. They may be roughly grouped into five different classes or types:—

1. Those having four-cylinder internal-combustion engines and transmission largely following motor vehicle lines. Thirteen entrants.

2. Those machines which follow in general what may be described as agricultural lines, being fitted with low-speed two-cylinder engines and having their transmission gearing more or less exposed. Fourteen entrants.

3. Self-contained tractors, where the implement forms to some extent an integral part of the machine. Three entrants.

4. Track-laying tractors. Four entrants.

5. Steamers. Two entrants.

We will deal in greater detail with the trials next week.

ANGLO-GERMAN TRADE CONTROL.—A Reuter's telegram from Cologne, says Mr. Charles Knott, president of the British Chamber of Commerce in Germany, announces that the German Government has consented in principle to a scheme for a clearing house to be established in Berlin under the control of a British official, who will have entire control of the licence department. Any goods leaving Germany or coming into Germany from Britain without a licence from this department will be confiscated. It is intended thereby to secure absolute and effective control of all exports from Germany to the British Empire and of imports from Britain into Germany. Mr. Knott is laying the proposals and details of the scheme before the Board of Trade in London.

MESSRS. YARROW AND CO.—As this firm has been principally engaged in the past in the construction of torpedo-boat destroyers it may be of interest to state that owing to the cessation of warship work they have been making the necessary arrangements to build merchant steamers up to 5,000 tons deadweight capacity, propelled either by reciprocating machinery, geared turbines or oil engines. They have recently secured an order for two 3,500 tons deadweight steamers, the work on which has already been commenced. They are, of course, continuing the construction of special shallow-draught river steamers on the Yarrow system, and have at present five vessels of this class in their works, in addition to a high-speed yacht propelled by geared turbines, Yarrow boilers and their system of oil burning. It may be of further interest to state that they are now building Yarrow patent water-tube boilers for land installations. They have on order at the present time one large installation fitted with their latest form of patent superheater for a big electric power station in England.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The hope of engineering employers to bring contracts up to date, secure a straight run on production, and press ahead with the latest schemes for pushing export trade, are again overshadowed, this time by the moulders' strike. No engineering centre is worse situated in regard to the strike than Sheffield. The number of moulders employed in the city's foundries exceeds 2,000, and upon them are dependent directly and indirectly nearly 50,000 workers in adjoining sections. Most of the large manufacturing concerns will be able to carry on for a fortnight; some perhaps for three weeks. But at the end of that time, if the moulders continue idle, engineering will be well on the way towards general paralysis, and a very serious state of affairs will result. The most serious aspect of the strike is not in its immediate effect on output, but the result it is likely to have on the new scheme instituted by the largest engineering concerns to make up for the undoubted slump in armament, naval shipbuilding and munition manufacture, by attracting a larger share of railway construction work both at home and abroad, and catering for the anticipated larger demand for electrical plant and machinery. The large armament firms hoped by this means to find an outlet for the greatly increased steel output of their South Yorkshire works and subsidiary concerns in other parts. Supplies of raw and semi-finished material are coming to hand rather more freely, except in the case of basic iron. From a producer's standpoint quotations for basic iron have been unremunerative for the past three weeks. The result is that several of the local blast furnaces have turned their attention exclusively to foundry pig-iron. Increased deliveries of the latter quality are badly needed. An easier tendency is already discernible in the market. Derbyshire furnaces are quoting 9*l.* to 9*l.* 5*s.* at works. Slightly higher values rule for the Lincolnshire product. Basic iron remains at 8*l.* 12*s.* 6*d.* to 8*l.* 15*s.* The market for forge iron is irregular, with a weak tendency. Cleveland makers are quoting considerably lower than local producers. Steel billet makers have a fair volume of work on hand. Prices are firm at the former level. Increased deliveries could be dealt with at the local works. The arrival of a small quantity of American and Belgian bar iron has relieved the situation at the steel works. South Yorkshire bar iron makers are able to report a slightly improved attitude among the workers. Evidence of efforts to increase output and banish "ca' canny" is also forthcoming at some of the largest steel works. One set of furnacemen have increased production from 170 tons to 340 tons per furnace per week, giving the works a gross annual increased output of nearly 1,000 tons. Makers of tramway material are receiving more inquiries for renewals and repairs. The Sheffield Tramways Undertaking proposes to relay 10,000 yards to 12,000 yards of track, at a cost of 70,000*l.* Uniform activity prevails in the lighter trades. Export business in files is very satisfactory. Output is much more in accordance with requirements now that a record number of file-grinding machines has replaced manual labour.

South Yorkshire Coal Trade.—House coal is in great demand. Merchants are making special efforts to obtain supplies to build up reserves for the winter. Stocking is much behindhand. Merchants are anxious to avoid the necessity of wiping off arrears and meeting current requirements during the winter months. Improvement in output at the pits continues, but so far has made little impression on the general demand, which keeps at a high level for all classes of fuel. Best steam hards are a strong market. Only a minor portion of export business can be entertained. Pressure on home manufacturing account is insistent. Practically the whole output of cobbles, nuts and slacks is going away on contract account. A fair demand is experienced for melting and furnace coke. Gas cokes are difficult to obtain. Quotations:—Best branch handpicked, 33*s.* to 34*s.*; Barnsley best silkstone, 33*s.* to 33*s.* 6*d.*; Derbyshire best brights, 31*s.* to 32*s.*; Derbyshire house coal, 28*s.* 6*d.* to 29*s.*; Derbyshire best large nuts, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.* 6*d.*; nutty slacks, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

CENTENARY OF THE DISCOVERY OF ISOMORPHISM.—A hundred years ago Eilhardt Mitscherlich communicated a paper to the Berlin Academy of Sciences in which the isomorphism of certain salts of metals (phosphates and arseniates in the first instance) was first pointed out. In the July issue of the *Zeitschrift für Anorganische Chemie*, G. Tammann, of Göttingen, publishes an article of 240 pages in commemoration of the event, dealing with the chemical and galvanic properties of crystallised compounds and their atomic relations. Mitscherlich came from Neuende, in Oldenburg, and was working in Berlin at the time.

COAL-SAVING IN AMERICA.—As is well known, considerable difficulty was experienced in America during the war in securing adequate supplies of fuel for manufacturing and domestic purposes. Greater attention was accordingly paid to coal economy than ever before and considerable savings were effected. Thus at Worcester (Mass.) 13 of the leading manufacturing plants consumed 27,104 tons of coal in 1918, as against 31,232 tons in 1917. The number of employees was, moreover, slightly greater in 1918. The greatest proportionate savings were effected in the plants which required least coal, as the large coal users had already given considerable attention to the question of coal saving.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Scarcity of the better qualities of Cleveland pig-iron is much less acute than it has been, but it is still very difficult to make a purchase for prompt delivery. Continental demand continues heavy, and with threatened curtailments of home consumption as the result of the ironfounders' strike, firms doing business abroad look forward to securing export licences with less difficulty and consequent expansion of foreign trade, though freights tend stiffer, and the adverse rates of exchange in the allied countries retard export business. Home users of foundry iron are fairly well bought. The lower qualities are nothing like so abundant as they were a few weeks ago, considerable quantities having been taken up of late for home purposes. For home consumption, No. 3 g.m.b. and No. 4 foundry are 160*s.*, No. 1 is 164*s.* and No. 4 forge 157*s.* to 160*s.*; whilst export rates are 5*s.* above these quotations.

Hematite Iron.—East Coast hematite iron is in only moderate request for both home use and for shipment abroad, but if licences were more freely obtainable exports would be heavier. Nos. 1, 2 and 3 remain at 200*s.*, for home use, and 205*s.* for shipment to foreign ports, and No. 1 is 202*s.* 6*d.* for home purposes and 207*s.* 6*d.* for export.

The Ironfounders' Strike.—Up to the present the ironfounders' strike has had little effect on trade. So far some 1,500 men in this district have come out, but the suspension of work at the foundries will soon seriously affect kindred traders. The strikers here appeared reluctant to leave work, but they felt they must fall into line with the foundrymen elsewhere.

Manufactured Iron and Steel.—Little new is ascertainable concerning finished iron and steel. Though slackness is noticeable in some branches, there is general healthy activity, and demand from abroad shows some improvement. Less anxiety is felt concerning American competition, but the fact that Belgium bar makers are offering bars at substantially less than home prices is somewhat disturbing. Inquiries for sheets continue large, and railmakers and plate producers are very busy. Export quotations are not fixed, but may be given as a little above the following, which govern the market for home business:—Common iron bars, 22*l.*; marked bars, 25*l.*; strip iron, 23*l.* 5*s.*; black sheets, 24*l.*; galvanised sheets, 30*l.*; steel strip, bridge and tank plates, 18*l.* 5*s.*; steel boiler plates, 21*l.* 10*s.*; steel angles, 17*l.* 15*s.*; steel joists, 17*l.* 10*s.*; and heavy sections of steel rails, 16*l.* 10*s.*

Foreign Ore.—Business in foreign ore is almost at a standstill, consumers continuing to hold off the market as they have considerable stocks, and substantial contracts made. Imports, however, show great falling-off, and this month's unloadings will be small compared with August arrivals. Rubio, of 50 per cent. quality, is 53*s.* 6*d.* c.i.f. Tees, and the freight Bilbao-Middlesbrough remains at 25*s.*

RESTORING RUBBER GOODS.—According to *Canadian Machinery*, articles made of rubber that have lost their elasticity through oxidation may be restored to their original condition by soaking in a mixture of one part of ammonia to two parts of water. The method is said to be particularly well adapted for the treatment of rubber bands, rings and small tubing.

THE RADIOACTIVITY OF RUBIDIUM AND OTHER ALKALI METALS.—In addition to the ordinary radioactive substances, which are all closely related to uranium and thorium, two elements of the highest atomic weights known, only two of the light metals of relatively small atomic weights, potassium and rubidium, seem to be radioactive to a certain extent. The nature of this latter radioactivity is by no means understood, whilst a great deal is known as to the character of the ordinary radioactivity. In case of the radium and the other radioactive elements there is certainly a decay of atoms. As regards potassium and rubidium we have no definite evidence of any decay. In discussing these problems in the *Physikalische Zeitschrift* of May 1 last, Otto Hahn and the late Martin Rothenbach point out that, whilst several investigators are convinced that these alkali metals emit β rays, α rays have not been discovered; it is on the other hand striking that the potassium salt deposits of Stassfurt are rich in helium. The radioactivity of the alkali metals might be due to some impurity; but no impurity has been traced, and the radioactivity observed is always proportional to the potassium percentage, *e.g.*, the intensity of the radiation from potassium which was first observed by N. Campbell at Cambridge in 1906, is very small; yet it was considered to be at least 10 times stronger than that from rubidium. Hahn and Rothenbach made their experiments especially on the sulphates of potassium, rubidium and caesium, with the aid of electroscopes of unusually large dimensions. The following are the conclusions at which they arrived. There is no indication of the presence in rubidium of some isotope; the β-rays from rubidium seem in penetrating power to stand between uranium X- and radium proper; the ratio of the activities is rubidium to uranium as 1 : 15, and rubidium to thorium as 1 : 10; if the life period of rubidium be 10^{11} years (which is uncertain), then the life period of potassium would probably be from three to seven times longer. Speculations have been made by others as to a possible production of strontium from rubidium, calcium from potassium, and barium from caesium; but such speculations appear to be quite arbitrary for the present.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Of late there has been a diminution in arrivals of shipping and the total number of vessels now in the various docks is lower than for some considerable time past. For the past week coal prices were generally steady, but to-day they displayed an easier tendency, and much will depend on the future shipping position. Buyers entertain hopes of sellers getting into difficulties in respect to insufficient supplies of tonnage, and are looking for a fall in values. Inquiries, too, are restricted by the fact that many exporters have exhausted their export licences for the September quarter, but as fresh authorisations are coming forward for the December quarter there is a prospect of a broadening demand in the near future. The inland demand for supplies and for bunker shipments to home ports remains active and in view of the recent reduction in outputs, the quantity available for export is reduced correspondingly. In the week ending September 13 outputs in the South Wales coalfield totalled 921,187 tons, which is about 54,000 tons less than in the week ending August 23. Exports, exclusive of Admiralty shipments, in the week ending September 19 amounted to 297,273 tons, of which 144,804 tons, or nearly 50 per cent., went to France. Shipments from Cardiff totalled 174,598 tons, from Newport 48,761 tons, from Swansea 53,417 tons, and from Port Talbot 20,497 tons. The docks are not now congested with shipping, and in consequence there is an improvement in tipping arrangements. Good quality large coals are worth anything from 80*s.* to 85*s.*, and best small steams from 60*s.* to 65*s.*, with ordinaries from 50*s.* to 55*s.* and inferiors from 40*s.* Coke is firm and scarce on the basis of 105*s.* Patent fuel is irregular with prices dependent on the individual circumstances of sellers ranging from 75*s.* to 72*s.* 6*d.* Pitwood is plentiful, with a poor inquiry at 55*s.*

A Freight Rate Muddle.—Recently a number of British steamers were diverted from the foreign to the home coasting trade by the directions of the Shipping Controller, who instructed owners to secure market rates. Nominally rates for the United Kingdom ports are limited, but the instruction to obtain market rates was interpreted as meaning that owners were to secure the best terms possible. In consequence, owners refused to sign charters under 20*s.* for small vessels to Liverpool. The Shipping Controller first of all offered 15*s.*, but this was refused, and after a number of contradictory messages from the Coal Controller and Shipping Controller the question was settled yesterday by a virtual surrender of the authorities to the owners, the Ministry of Shipping agreeing to 20*s.* for vessels up to 1,000 tons deadweight for Liverpool, 17*s.* 6*d.* from 1,000 tons to 2,000 tons and 16*s.* 6*d.* for 2,000 tons and over, with 1*s.* extra in each case for Manchester or London.

PERSONAL.—Dr. J. G. Stewart has been appointed Lecturer in Engineering at University College, London, for which post applications were recently invited.

NORWEGIANS AND BRITISH SHIP LOAD-LINES.—*The Times* Christiania correspondent telegraphs: An important conference, arranged on the initiative of the Norwegian Shipowners' Association, by its president, Mr. Fearnley, between the representatives of Lloyd's Register of Shipping, Messrs. W. S. Abell, G. R. Mares, R. J. Jones, and the Norske Veritas was opened on Wednesday, the 17th inst., for the purpose of smoothing the present divergencies between the British and the Norwegian freeboard rules for shelter-decked boats. Owing to the Norwegian rules being considerably stricter than the British rules, several inconveniences have arisen, and boats bought in England for Norwegian account have suffered considerable loss of tonnage on arrival here, through the difference in the rules. After an interesting debate on this subject, the conference further discussed the question whether Norway should adopt the British load-line rules pending the submission of the matter to the International Conference. It was agreed to appoint a committee, which, on the 20th inst., submitted a report to the effect that the establishment of uniform rules as to the strength of materials was desirable, whereby boats built in England to a particular class at Lloyd's would be able to obtain the same class in Norway.

LONDON COUNTY COUNCIL TRADE SCHOLARSHIPS FOR BOYS, 1920.—Courses of instruction are provided in London at day trade schools for boys who intend to enter skilled trades with a view to becoming skilled workers, foremen and managers. The instruction is specialised to prepare boys for entry into particular trades, to give a knowledge of the underlying principles of the trade and a practical training in trade methods, and to improve their general education. The Council offers 263 scholarships tenable at these schools. By means of these scholarships, boys may secure free education (with a maintenance grant) to prepare them on leaving school to take up either apprenticeships or employment in skilled trades. The principals of the trade schools will be glad to advise parents and to assist them, as far as possible, in placing boys who have satisfactorily followed the courses of training. The next school year in the trade schools will commence in April, 1920, when successful candidates for these scholarships will begin their training. Parents should apply to the Education Officer, L.C.C. Education Offices, Victoria Embankment, London, W.C. 2, for a list of the trade schools and make an appointment with the principals and personally visit the schools. It is difficult otherwise to gain an idea of the nature of the work done and of the excellent equipment provided. The applications for admission to a school must be made before October 4.

NOTICES OF MEETINGS.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Tuesday, September 30, at 7 p.m., at Caxton Hall, Westminster, a paper by Mr. R. P. C. Sanderson, Member of Council, London, will be read on "Notes on Recent American Locomotive and Wagon Practice."

THE JUNIOR INSTITUTION OF ENGINEERS (MIDLAND SECTION).—Wednesday, October 1, at 7.30 p.m., the annual general meeting will be held at the Chamber of Commerce, Birmingham, to be followed by an informal discussion opened by Mr. G. W. Costain.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, October 3, at 7.30 p.m., at 39, Victoria-street, S.W. 1, "The Deduction of Formulæ from Plotted Figures," by Mr. A. J. Paxman, Associate Member. Friday, October 10, at 7.30, at the Shipping, Engineering and Machinery Exhibition, Olympia: Lecture, "Some Hydraulic Exhibits," by Mr. H. S. Hele-Shaw, D.Sc., LL.D., Hon. Member.

THE LONDON ASSOCIATION OF FOREMEN ENGINEERS.—Saturday, October 4, at 7 p.m., at Cannon-street Hotel, London, E.C., "Elimination of First Stretch in Steel for Reinforcing Concrete," by Mr. A. W. C. Shelf.

COLUMN APPARATUS FOR TECHNICAL WORKING WITH GASES.—W. Bormann describes in the *Zeitschrift für Angewandte Chemie*, of May 20 last, various forms of the Kubierschky column apparatus for washing, boiling, purifying, absorbing and distilling gases, and for the recovery of the solvents used. These apparatus were first described in 1915, and seem to have undergone considerable development since then, and to have found wide and varied applications. They act in general on the counter-current principle, but are made in various modifications to adapt them to their special purposes.

PULVERISED COAL AS A BOILER FUEL.—In a paper published in a recent issue of the Journal of the American Society of Mechanical Engineers, Messrs. E. H. Welles and W. H. Jacobi give the following list of the advantages and disadvantages of pulverised coal when used in boiler furnaces. The merits are: (*a*) If ground sufficiently fine the entire combustible content of the coal can be burned, thereby effecting fuel economies not hitherto allowable even with the better-grade coals burned under favourable conditions; (*b*) It permits of the use of all grades of coal, including peat and lignite, with an approximately equal degree of thermal efficiency for the same service, and increases very materially the energy that can be derived from the world's supply of coal; (*c*) it possesses very largely the facility of control and combustion of oil and gas fuels, thereby placing coal on a parity with these fuels. The limitations of pulverised coal are: (*a*) The very high temperatures attending its efficient combustion and the unsteady mode of its deflagration, necessitating special furnace construction to secure reliable service and to realise the possible economies it affords, preclude its ready application to existing equipment; and (*b*) the operating cost and attention required to maintain the necessary apparatus may more than offset the fuel economies that can be effected in small independent service; (*c*) the presence of ash which may not always be collected and held under control; (*d*) the human element which will not submit to the peculiarities of its nature.

A RECORD VERTICAL-RETORT CONTRACT.—We are indebted to *The Gas Journal* for the following particulars of a most important installation of vertical retorts at the Glasgow Corporation Gas Works: "In these times the gas industry is faced by the two facts that there is a tremendous scope for increasing the gas business, and that, in view of producing costs, it is necessary to bring to bear in the manufacturing system every possible means to economy. These are points that have been fully realised by the Glasgow Corporation Gas Committee and their technical advisers; and their confidence in both the future and the economies of modern carbonising practice is shown by the fact that they have placed an order with the Woodall-Duckham Company, Limited, which (so far as we are aware) is a record single contract for continuous vertical retorts in any part of the world. The plant is destined to carbonise 1,350 tons of coal per day, in 192 retorts, each of an approximate capacity of 7 tons per day. The retorts will be arranged in eight benches, each being built with six producers. An interesting feature of the installation will be the equipping of the benches with boilers to utilise the waste heat of the settings; the steam being employed for steaming the charges, and the surplus for other operations about the works. The utilisation of waste heat in all works is one of the strong planks in the platform of the fuel economists; and Glasgow will prove on a large scale what can be done in this direction by utilising the waste heat from the new carbonising plant. The contract will include the necessary coal and coke-handling plant, and the sum involved will be upwards of 500,000*l.*; but the exact amount has not yet been definitely settled, as certain details in parts of the plant have to undergo modification and adjustment so as to suit the requirements of the department. The plant is to be erected at Provan, on which site the late Mr. William Foulis carried out his last great work as a gas engineer, and the plant and operations at which have since been the pride also of his successor (Mr. Alexander Wilson), who, as formerly Mr. Foulis's chief assistant, had a good part in their origin—particularly in connection with the outside producers that were developed for the heating of the retort settings."

HELL GATE BRIDGE, NEW YORK.

MR. GUSTAV LINDENTHALL, CHIEF ENGINEER.

(*For Description, see Page* 416.)

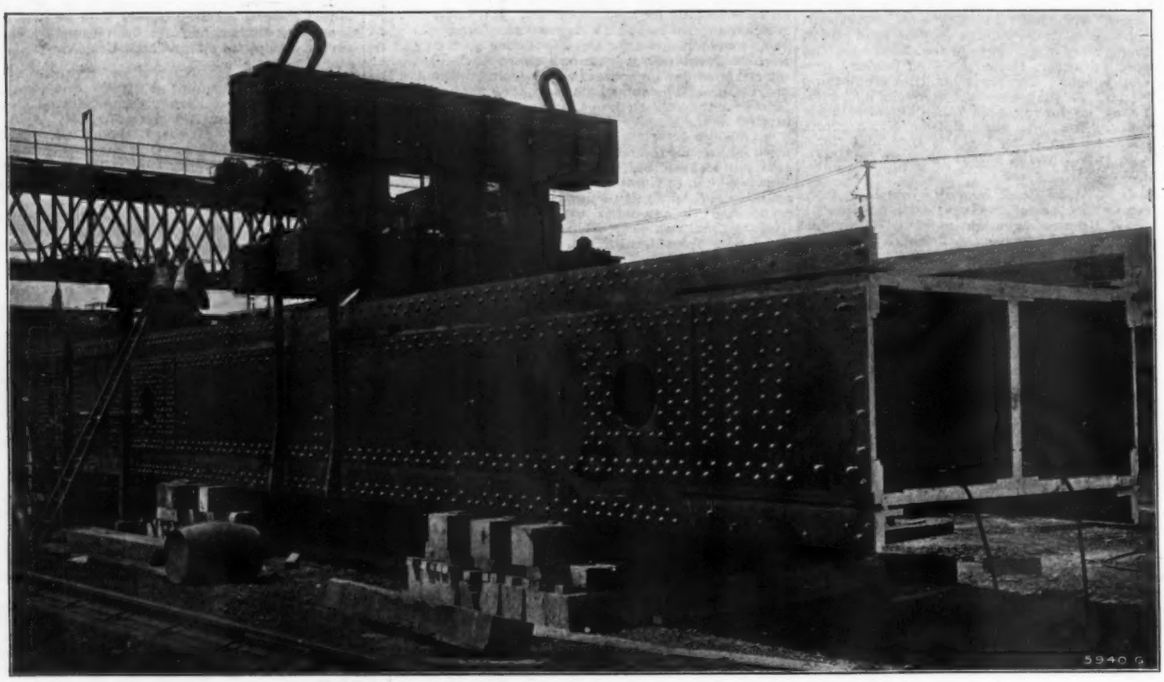


FIG. 39. BOTTOM CHORD SECTION WITH LIFTING DEVICE.

FIG. 40. TWO SPECIAL CARS—CAPACITY 75 TONS EACH.

HELL GATE BRIDGE,

MR. GUSTAV LINDE, CHIEF

(For Descr... Page 41

Fig. 41. Part of Backstay; Long Island Side of Bridge.

Fig. 42. Travellers Erecting Backstay and Main Arch Span.

BRIDGE, NEW YORK.

LINDE (CHIEF ENGINEER.

r Descr Page 416.)

FIG. 43. BACKSTAY COMPLETE AND CONNECTED AT PANEL POINT 11.

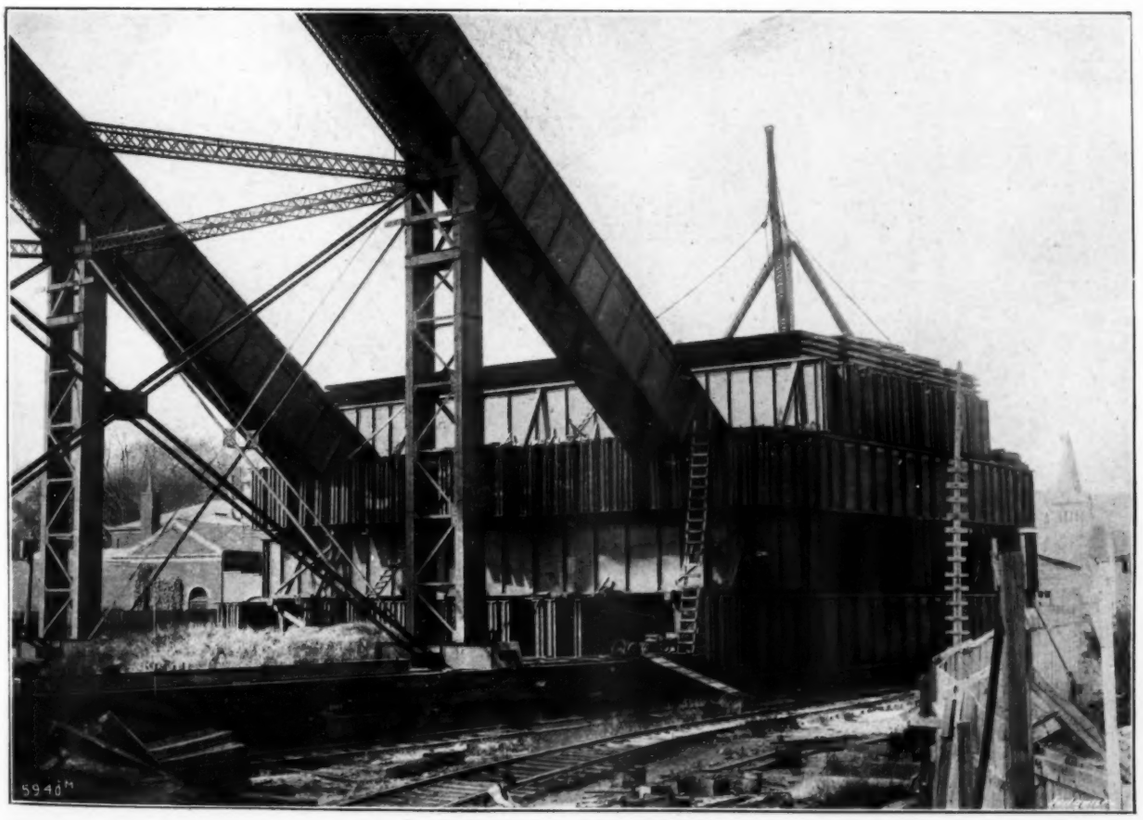


FIG. 44. BACKSTAY ANCHORAGE ON WARD'S ISLAND.

AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Turner and Henderson, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
BELGIUM, Brussels: E. F. Satchell, 86, Rue du Tabellion.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers. Montreal: Sells, Limited, 302, Shaughnessy Building, McGill-street.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banque. For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink and Co. Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan, and any post-office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son.
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Cape Town: Wm. Dawson and Sons, 31, Long-street.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication, and certainly not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£2	9	0
For Canada—			
Thin paper copies	£2	5	0
Thick " "	£2	9	6
For all other places abroad—			
Thin paper copies	£2	9	6
Thick " "	£2	14	0

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements 35 and 36, Bedford Street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON,

TELEPHONE NUMBERS—3663 and 8596 GERRARD.

CONTENTS.

	PAGE
The British Association	397
Recent Machine Tool Developments. — No. VI (*Illus.*)	400
The Iron and Steel Institute	403
Industrial Notes	406
Portable Military Bridges (*Illus.*)	408
The Building of Airships	409
The Institute of Metals	410
The Tractor Trials at Lincoln	410
Notes from South Yorkshire	410
Notes from Cleveland and the Northern Counties	411
Notes from the South-West	411
Notices of Meetings	411
Scientific and Industrial Research	413
Specialisation	414
The James Watt Centenary (*Illus.*)	415
Hell Gate Bridge, New York (*Illus.*)	416
Moulding-Sands for Non-Ferrous Foundry Work (*Illus.*)	418
On the Woody Structures of Fractures of Transverse Test-Pieces taken from Certain Special Steels (*Illus.*)	421
Fuel Economy in the Iron and Steel Manufacture	423
Fuel Control in Metallurgical Furnaces (*Illus.*)	425
Fuel Economy in the German Iron and Steel Industry	428
Catalogues	430
Powdered Fuel for Puddling Furnaces	430

With a Two-Page Plate of the HELL GATE BRIDGE, NEW YORK.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 411.

ENGINEERING.

FRIDAY, SEPTEMBER 26, 1919.

SCIENTIFIC AND INDUSTRIAL RESEARCH.

As a nation we are frequently accused of taking shortsighted views. The charge has perhaps some foundation in fact, but in the fields of politics and sociology the attempt to forecast and provide for a far distant future not uncommonly results in disaster. Life is so complex, that the wise statesman, though he may not be satisfied with the "one step" held sufficient by Newman, will do well to proceed tentatively with even the most plausible of policies. In science and technology, however, a different rule prevails, and whilst Germany's long planned and laboriously organised scheme for the subjection of the world has resulted in her own downfall, the same qualities of patience and industry yielded her a rich return in her applications of science to industry. The German has made no demand for immediate returns. The work was pursued without haste but without rest, in accordance with Goethe's motto, and the results thoroughly justified the confidence of the German financier and business man in the judgment and competence of his experts. In England in pre-war days the expert was largely at a discount. Whilst American owners of rubber plantations in the East selected their assistants and overseers from the ranks of those who had graduated in botany or chemistry, with us the main qualification asked of the aspirant for such a post has too frequently been that he should be a Public School boy. How far matters will be changed by the experiences of the past five years remains to be seen.

The value of science became so obvious under war conditions, that the establishment of the Committee for Scientific and Industrial Research and its endowment with 1,000,000*l.* met with little or no opposition. It was recognised practically universally that the masters of words, such as it has been the main aim of our traditional system of secondary education to produce, must give way to the creators of ideas, and the official whose principal qualification lay in his ability to write a readable report on any given subject, had to surrender the direction of whole fields of endeavour to others whose literary style might possibly be at fault, but who were endowed with insight and imagination.

Ruskin, master of English prose as he was, would have proved a poor substitute for men like Sir Herbert Jackson, who gave such effective help towards the solution of the problem of supplying the insistent military demand for varieties of glass previously obtained from Germany, or for those who gave us the Stokes gun or the tank, which in both cases were only forced on the departments concerned by extraordinary persistency and pertinacity.

The war is over, and the Ruskin school which holds with Plato and Socrates that truth can be reached by *a priori* reasoning unchecked by observation or experiment, is still numerically very strong, and quite naturally includes a very large proportion of our journalists and public men. There is therefore some danger that a strongly backed movement may arise urging the abolition, or more probably starvation, of the Department of Scientific and Industrial Research, as one step towards that drastic reduction in our national expenditure which all parties are agreed is essential if bankruptcy is to be avoided.

Our characteristic tendency to demand results immediately profitable, will undoubtedly be worked for all it is worth by the leaders of any movement of this kind, and it is fortunate therefore that the department, though established barely four years, can already point to a number of cases in which investigations aided by it have been of direct benefit to certain of our industries. Much of its energies have, of course, been directed to warlike ends. The Department has assisted the Admiralty in dealing with the enemy's mines and submarines, and the Air services, in facilitating the work of flying men at high altitudes; whilst, as is well known, the staff of the National Physical Laboratory has had to be largely diverted from the normal pursuits of its members and devoted to the solution of Service problems. Indeed it was the consequent severance of the links that had been established between our industries and the Laboratory that made it imperative for the Royal Society to abandon their responsibility for the Teddington undertaking, since there was a serious prospect that the firms who had perforce learnt to do without the help of the N.P.L. would neglect to renew their old relationships on the establishment of peace.

The Committee, whilst establishing and financing a considerable number of research sub-committees directly responsible to it, has throughout held in view the desirability of assisting researches initiated by the industries themselves. This is most important as a centralisation of research would almost certainly result in stagnation, independent centres of thought being essential to progress. The plan followed has been to contribute liberally towards the costs of research committees organised by these industries directly concerned. Of course, no one expects that organised research of this kind is likely to lead to revolutionary changes in our manufacturing methods. The creation of wealth on a large scale is commonly due to individual genius, a type of humanity which works badly under the direction of a committee, which has commonly to content itself with research of a somewhat humdrum character. The accumulated effect of a whole series of small improvements may, however, lead to very striking results. In the organic world Darwin attributed the whole development of the species to a long continued process of this kind, and we believe that biologists are returning to the view that much has been effected in this way, although there is a greater tendency than formerly to emphasise the part played by the "mutations" or large variations, which in the organic world correspond to the revolutionary work in industry of the man of genius.

Of these research associations, 17 have been licensed or approved up to date. In one or two cases, however, of which the shale oil industry is an example, the enormous increase in the cost of labour, has rendered manufacturers so doubtful as to the future of their trade, that the attempt to form a research association has been abandoned. The help afforded by the Department is based in the main on the amount of the contributions directly subscribed by the industry concerned. In exceptional cases, however, for example that of those "key" industries in which the total annual turnover is too small to provide adequately for the researches contemplated, the contribution of the Department is increased. Thus in the case of the British Scientific Instrument Research Association the Department has arranged to contribute 64,000*l.* or 70,000*l.* if the members will themselves provide an immediate contribution of one-tenth these amounts. Similarly the Glass Research Association is to receive 20,000*l.* per annum if its members provide 5,000*l.* per annum themselves.

Results of industrial importance have already been attained in glass-making, china-making, mining and metallurgy. It is announced that matters have now progressed so much that the manufacture of hard porcelain on a commercial scale is to be undertaken forthwith. The history of the manufacture of china in Europe is of considerable interest. The Continent busied itself mainly in attempts to imitate the original porcelain of China, and when success was finally achieved the work was carried out for the most part in State-owned factories, in some of which the operatives were treated as close prisoners in the endeavour to prevent a knowledge of the factory methods spreading to other lands. Britain on the other hand, by private

enterprise, invented and introduced a new form of china, having in some important regards considerable advantages over the Oriental type. The latter, however, is much superior to "bone" china for certain limited purposes, but its manufacture was neglected here until the war made it impossible to import from the Continent the supply required. This led to the researches by Dr. Mellor and Mr. Moore, which proved that we could perfectly well supply our own requirements in this regard.

In pre-war days refractories were also imported on a large scale from the Continent. In part this was due to the circumstance that the majority of our makers were working on a comparatively small scale, so that there were difficulties in providing for a proper scientific investigation of the problems at issue. Here again the leeway has to a large extent been made good. The Seger cones, no longer obtainable from abroad, were soon replaced by equivalents prepared by Dr. Mellor, and we learn from the report that conspicuous success has attended the experiments made in the manufacture of gas retorts. A new method of casting 5-ft. retorts has proved its value, and thus a great improvement has been effected at the cost of a few hundred pounds. The Photographic Research Association have discovered a method of staining wood black or grey all the way through, and this process will doubtless find its application in more than one industry. The Committee which have been investigating abrasives and polishing materials have succeeded in producing a new form of rouge which is quicker in action and altogether more satisfactory than any previously attainable.

In view of the present prices of tin, it is of interest to learn that by improved methods of treatment developed with the aid of the Department, it is expected to increase the present yield of the Cornish ores by no less than 11 per cent.

Not much progress has been made in the purely engineering researches. The Committee on Lubricants have accumulated a good many data and discovered some striking peculiarities in the behaviour of different lubricants. The matter is, however, very complex, and much yet remains to be done before our knowledge of lubrication can be considered reasonably adequate. The Department has contributed to the cost of the work in hand of the Steam Nozzles Research Committee appointed by the Institution of Mechanical Engineers. This research has, however, been held up, in part by the inordinate increase in the cost of apparatus, but mainly by the difficulty, indeed impossibility, of securing under war conditions the necessary staff of observers.

In view of the shortage of fuel, it is unfortunate that the work of the Fuel Research Board has been greatly delayed by difficulties with the foundation of the Research Station at Greenwich. Highly inconvenient as the present high cost of fuel is, the evil is not entirely unmixed. Unquestionably we have in the past been very extravagant in the use of our magnificent coal supplies. To some extent no doubt this was unavoidable. The steam engine would never have been developed had the pioneers been required to attain the standards of fuel economy now known to be practicable, nor could the heavy steel and iron industries have been built up had fuel economy been a *sine qua non* at the outset. Unfortunately, however, practices unavoidable in pioneering days were retained, and cheap fuel and cheap labour made it possible to carry on works with a minimum of constructive thought. Even in the 'eighties visitors to American steel works were struck by the scanty population of the workshops. Mind had been used to supplant the need for muscle, and machinery devised and installed by which a small number of highly-paid operatives were able to secure remarkable outputs. As with labour so with fuel. Until the advent of the steam turbine the most economical steam engines were made on the Continent, as the British factory owner considered the capital cost of installing such economical engines as insufficiently offset by the reduced consumption of fuel at its then price.

The householder has also been extravagant with fuel, the kitchen range being a notorious coal-eater. This matter has been investigated by Mr. Barker for the Building Materials Research Committee, and there is very prospect of a decided improvement being effected. In this connection it is of interest to note that a Committee appointed by the Institution of Mining Engineers has found that it is possible to control the temperature of deep mines by adequate ventilation, so that coal may be won from depths hitherto considered inaccessible. The Coal Industry Commission recently fixed on 4,000 ft. as the absolute limit of depth for a coal mine, but the Committee above referred to, find that this can be extended to 5,000 ft., and with special precautions to even greater depths. An important addition is thus made to our fuel reserves as hitherto estimated.

The Industrial Fatigue Research Board has continued its work. In reports already published, cases have been brought forward in which a reduction of the hours of labour has actually been accompanied by an increase of output. On the other hand, recent reductions of hours worked in the engineering trades are said to have resulted in a decreased production almost exactly proportionate to the decrease in the hours worked. In part this may be due to the lapse of time being insufficient to establish the ultimate consequences of the change. The first effect of such a change is almost certain to be a reduction of output, but in some cases, at least, it has been found that, after a few months, matters have so adjusted themselves that the hourly output has increased sufficiently to compensate for the reduction in the time worked.

At any rate, it seems certain that maximum outputs can be secured only by a substantial increase in management expenses. Foremen have too commonly been overworked and underpaid, and far too little thought has been expended on making matters easier for the operatives. A workman can chip and file a casting even if he has to twist himself almost into a knot to get at it, but it will commonly prove cheaper in the end to avoid the necessity for such contortions. The importance of such considerations was very clearly shown in one shop during the war, which took up the manufacture of small shells. At the outset the intended output was hardly half of what had been anticipated, and a notable increase was effected by merely arranging that the blanks should be delivered to the workman at hand height instead of being piled on a heap on the floor near his machine, so that he had to stoop to pick them up. From first to last the recently issued report of the Committee of the Privy Council for Scientific and Industrial Research is suggestive and instructive.

SPECIALISATION.

SPECIALISATION is commonly considered as a distinctly modern element in manufacture, and its benefits in economic production are assumed to have been realised only in recent times. Actually it is the extensive application of a very ancient realisation. There was once a time in the dawn of history when each individual produced all his needs, or failing some complementary qualities in his next of kin, went without. Later we find certain men set aside for special vocation as, for instance, priests and kings, soldiers and sailors, blacksmiths and millers —they could produce greater output with less effort if trained to specialist ends; the continuation of the process in due time made the Ford car a possibility. Each village community, after man lost to some extent his desire to club every stranger and learnt that co-operation meant security, found employment for specialist artisans—saddlers, armourers, smiths, wheelwrights, carpenters. Now specialisation did not invent the internal-combustion engine, that was more or less individualist research, but modern processes of manufacture are the outcome of the logical necessity which set apart the first carpenter or the first smith.

Curiously enough the wheel of time has turned full circle, and the industrial operative of to-day has no need for definite and specific skill in a trade sense. Human muscle and the co-ordination of mind, eye, and training, has been superseded, and the propellant power applied to the tool is now mechanical power, so that former skill of craft has been penalised. We are reminded at due intervals, and the advice becomes more insistent, that the remedy for all engineering ills is specialisation. What should, however, be insisted upon is that the cure for competitive manufacturing troubles is the said remedy.

A vast difference exists, and must continue to exist, between manufacture and the field of the engineer—between the craftsman and the operative. The opposed activities occupy different spheres, and should be so regarded. The engineer is a pioneer pitting trained skill against individual problems, the manufacturer is not concerned with original solutions but with settled processes and quantity production. It depends altogether upon the work in hand whether specialisation is expedient: no panacea, whether medicinal or commercial, is of universal application.

Evolution in a mechanical sense covers a broad field. First comes original discovery, the work of the scientist, then reduction to the realm of practical things, the latter a work of great magnitude in many cases. Subsequently comes a period when improvement is rapid, and constant change the rule; finally, by process of time, method, material and design become crystallised, the market expands as the cost is reduced. Large demand justifies specialised manufacture only in the last phase. As a matter of fact, everything passes through the series of stages indicated, while there are always numerous things which for varying reasons never get to the finality of specialised manufacture, where sub-sectionalised labour and minute subdivision are warranted.

It is possible that when mechanical invention has exhausted itself—it must be remembered that it is the outstanding feature of the present age—when all the secrets of material and mechanism are discovered, or when the age pursues another activity—then manufacture will obey mathematical law with the symbols of capital, labour and supervision in a single equation. Until this period is reached, and the eventuality is not yet in sight, the place of the skilled engineer and mechanic who bridge the gap between discovery and popular need will be essential.

Specialisation is not a very modern discovery even in its present aspect. Whitworth foreshadowed its trend quite ably, and it was always realised that quantity production led to revision of process and reduction in cost. The reason which explains why the advent of specialisation in its modern guise was delayed was that sufficient quantity of one manufacture could not be secured to render interchangeable organising methods possible, save only in the case of firearms. It was the sewing machine, the bicycle and later the automobile which permitted the adoption of the methods now held up as a paragon of logical perfection. The vast extension of finely-subdivided labour in the field of munitions is due first to a fixity of design and second to quantity; it is merely the original methods of rifle manufacture upon a larger scale.

Standardisation and all it implies can only be successful where some finality in design is reached, it cannot be applied in an intermediate period where alteration is rapid and progress the rule. Only where vast quantities are involved with design fixed for a considerable period, can the skill of the craftsman be exchanged for the semi-skill of the operative. The method followed must be conditioned by circumstance and the ability to transfer skill or adapt machines is essential while evolution is the rule. The general application of munition methods and so-termed scientific methods to normal trade output is manifestly wrong as a settled and final conclusion.

A large proportion of the engineering work of the world consists of designs to special requirements to which specialist manufacture is inapplicable in the sense of the motor car or munition production. The Ford car is notorious not so much because it is a standardised production but because it is probably the most extensive article so produced. Bridges, ships, locomotives, boilers, marine engines, cannot be standardised in the same sense, nor indeed can anything which demands varying design to differing requirements. The 5,000-ton cargo tramp could be standardised perhaps—the quantities built would allow it; passenger vessels could not be so treated. There is room for an argument to justify less divergence in locomotive stock, each railway, for

example, designs its own engines, which differ, but the locomotive is far from being a settled and final product even now. It is safe to infer that specialised production in the main must be kept within limits of size, thus introducing another factor beside quantity. Broadly, detail can be standardised more readily than design.

Again, it has been rightly pointed out that vast schemes of output of a single type can only be applied where demand can be foreseen and closely estimated, where for instance there is a huge domestic demand highly protected by tariff. Where foreign competition is forestalled, specialisation is thereby rendered easier. If the manufacturer has a certain large preserve to supply, his additional export business is stabilised by normal home demand. Export then becomes merely an extension of the home field, not of necessity the greatest market. Where differing markets demand alteration and adjustment in design or type specialisation is less applicable.

Every country is from time to time reminded by its foreign representatives that the tendency to force existing design upon an overseas market in place of studying requirements and altering standard articles to suit local conditions is a proceeding fraught with danger in international trade. Local circumstances or climatic conditions radically alter the character of desirable articles. This is a valid argument against too intensive a cultivation of standardisation and rigid specialisation.

The danger attendant upon acute specialisation is easily realised; it is in effect the snatching of present profit as against future progress. Certain things universal to-day are made obsolete by progress in a few years; there are few men who do not prefer more than one iron in the fire. Capacity for adjustment to environment is hampered by the outcome of rigid specialisation. Transferable skill or plant is counselled by commonsense and is a measure of protection against obsolescence.

Specialisation in an acute form is rather like being dependent upon a single customer who may decide to manufacture for himself, trade depends upon numerous customers for stability, and national manufacture in turn depends upon capacity to fill varying needs. Few workmen regard distinct and unequivocal specialisation without misgiving; their expertness may in time be entirely scrapped by change or improvement. Adaptability of skill and organisation of plant mean the possession of fluid as against fixed assets.

The result of the work of every inventor is to break up settled practice, unfortunately for acute specialisation there is no means of calling a halt to invention, and for this reason alone the specialisation of to-day may be abrogated by the progress of to-day leading to new specialisation to-morrow. This is not to say that specialisation of a rational type has no virtue, but before throwing overboard a genuine bone it is as well to be certain that the attractive shadow is just as valid. In its logical meaning specialisation means confining effort within a very narrow tolerance, the more limited the field the greater the benefits, but the dangers are also multiplied.

Manufacture upon pious hope of a market is pure speculation, and while trade in its broadest aspect means the assumption of risk, there is a difference between the investment in Spanish gold and the attitude of a miser who starves rather than spend upon necessities. Somewhere between doing anything and doing a single detail lies the choice open, the two extremes are in effect not so very widely apart in their returns. The incongruity is less the more the facts are realised.

Transferable skill is of instrinsic value whether it is the possession of an individual or a limited company. Specialisation has all its eggs in one basket, and the particular basket needs continuous and close scrutiny, and because greater risk is assumed greater returns are justified. That industry in some quarters could do with more specialised methods may be true, but that a broader basis of effort would be beneficial elsewhere is equally a valid contention. Danger lurks at both extremes of the manufacturing scale, and certainly where a country is mainly dependent upon export trade there is opportunity for the exercise of both activities. It is impossible to dogmatise; the question of specialisation in a universal sense is obviously a danger, it depends upon the precise article, the volume of demand, its universality of utility apart from local conditions and numerous other factors.

THE JAMES WATT CENTENARY.*

CONTINUING our report of the Watt Centenary meetings we will deal first with the two lectures given on the forenoon of Wednesday, September 17. These were both given in the Medical Theatre of the Josiah Mason College, where a large audience which included many eminent engineers and men of science had assembled to hear Sir Oliver Lodge discourse on "Sources of Energy." The chair was taken by Mr. C. H. Wordinghan, president of the Institute of Electrical Engineers, who introduced Sir Oliver as one of those few scientific men whose name was equally familiar to the scientific and the general public.

The lecture may be considered as an interesting appendix to the address delivered by Sir Charles Parsons at the recent British Association meeting at Bournemouth. On that occasion Sir Charles emphasised the necessity of discovering new sources of energy, if Great Britain were to continue to support her present large population. Sir Oliver Lodge discussed in his address one possible source of this energy, highly "available" from the standpoint of thermodynamics, but, perhaps fortunately as he pointed out, hitherto inaccessible to the engineer. On this subject Sir Oliver is particularly well qualified to speak, as he was, we believe, one of those physicists who, guided by theoretical considerations, were, at the time of Becquerel's remarkable discovery of radio-activity, on the verge of undertaking experiments in search of just such a property as Becquerel found.

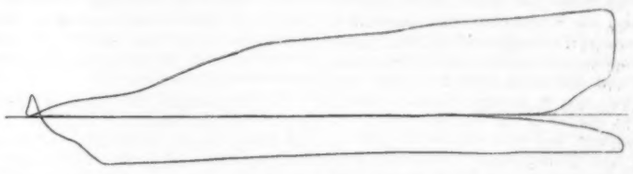


Diagram taken on September 18, 1919, from the first engine made for sale by Boulton and Watt in 1776. The indicator used in taking this diagram was the first made by James Watt in 1785, and was lent from the Boulton and Watts Relics presented to the Birmingham Corporation by Mr. George Tangye. The engine has a cylinder 32 in. in diameter and 72 in. stroke, and was running at the time the diagram was taken, at 14 strokes per minute. Scale of spring 15.4 lb. per inch.*

In opening his discourse, Sir Oliver Lodge drew attention to the fact that the discovery of radio-activity had proved, as was already believed from theoretical considerations, that an immense amount of energy was locked up in the atoms, but that this energy was at present inaccessible. He saw, however, no reason why this condition of affairs should continue. This store of energy resulted, he said, from the very structure of the atoms and was enormous in quantity. If it could be utilised on any extensive scale the whole conditions of factory life would be ameliorated. There would be no smoke from imperfectly burnt fuel, or dirt from the transport of coal and ashes. The power would be most compact and very clean. Indeed, its very concentration might lead to occasional explosions due to the energy being liberated more rapidly than intended. Nevertheless this drawback notwithstanding, the conditions of utilisation would, no doubt, be good on the whole, and possibly some one standing 100 years hence where the speaker stood now would be able to tell how the feat of developing this source of energy had been accomplished. For the present, however, we were merely at the beginning of the utilisation of atomic energy.

As instancing the amount and degree of concentration of this energy, Sir Oliver said that the disintegration of one grain of radium gave out sufficient energy to raise the temperature of one ton of water from the freezing point to the boiling point. In fact, the energy set free by the disintegration of radium was a million times as great as that generated by the combustion of an equal weight of hydrogen. On the other hand, the combustion of hydrogen could be controlled, whilst the break-up of radium was extremely slow and not under control. What happened was that every now and then some individual atom of a mass of radium, shot off an α particle. Other α particles were shot off in succeeding transformations, the final residue being common lead. There were radioactive substances still more energetic than radium, but as a necessary consequence they were correspondingly more rare. Of 3,000 atoms of radium, one on the average got each year into an unstable condition and fired itself off, so that radium had a relatively long life. The number of atoms in even a milligramme (about $\frac{1}{70}$ grain) was, however, extremely large, so that a milligramme of radium fired off nearly 30 million shots per second. These shots moved at a prodigious velocity, equal to about one-fifteenth that of light, and their energy was accordingly enormous. At present this energy was inaccessible. In fact, each atom of every metal had a vast store of energy locked up in it, but most of them were quiet about it, whilst the radioactive elements liberated this energy spontaneously without external stimulus. Could a stimulus be found a first step would be made towards the utilisation of the energy in the atoms; and if ultimately we were able to utilise the whole of it, we would be able to find sufficient in an ounce of matter to raise the whole German Fleet and pile it on top of a Scotch mountain. To repeat, in each ounce of a metal there were locked up millions of foot tons of energy, at present quite inaccessible. Perhaps it was a good thing that the stimulus required to release this energy had not yet been discovered. It would place enormous powers for evil in the hands of such an uncivilised nation as we had had to live with during the past five years, and it would be well that the human race should advance further in morals and brains before the momentous discovery was made. If the power got into the wrong hands the very planet might be unsafe, since a liberation of the atomic energy on a large scale would be sufficient to blow it up. Sometimes a new star appeared in the heavens, evidently as the result of some terrific explosion. Whether this were due to the fact that some inhabitant up there had made a discovery or not he was unprepared to say.

He had already, Sir Oliver continued, stated that scientists did not yet know how to utilise the atomic energy. They were, however, on the verge of beginning to use a small fraction of it. Wireless telephony was based on the use of electrons (liberated from the atoms) to form a magnifying relay, the degree of magnification being in some cases as much as 1500. The electronic relay responded instantly to every fluctuation of pressure in a way incomparably superior to any mechanical relay. By using this electronic relay for wireless telephony the articulation at the receiving end was accordingly perfect, and we had in this way taken a first practical step in the utilisation of the atomic properties of matter.

Towards the end of the lecture we noticed the arrival of the American Ambassador (the Hon. J. W. Davis) while in the interval between Sir Oliver's and the succeeding lecture the chairman of

* For previous articles relating to the James Watt Centenary, see pages 229, 249, 286, 305 and 385 *ante*.

* The engine here referred to was first erected at Smethwick, where it worked until 1892 for the Company of Proprietors of the Birmingham Canal Navigation. The engine was re-erected and preserved by the Company at Ocker Hill in 1898. The engine was illustrated by us on page 286 of our issue of August 29 last.

the Local Committee reminded the audience that representatives were present not only from America but from France, Sweden, Japan and Australia.

Presided over by Dr. Blackwood Murray, the second lecture, written by Professor J. D. Cormack, Regius Professor of Engineering in Glasgow University, and in collaboration with Emeritus Professor Archibald Barr, was delivered by the former. It was entitled "The Model of the Newcomen Engine Repaired by James Watt," and was illustrated by numerous slides illustrating the development of the Newcomen engine. The model, said the Professor, was one of the most prized treasures of the University, and if permission could have been obtained for its temporary removal for exhibition elsewhere it would have been in Birmingham that day. He hoped its absence would not reflect in any way on the cordiality which he and Dr. Barr as the representatives of the Court and Senate of the Glasgow University, brought to the city of Birmingham.

In his lecture, Professor Cormack laid stress on the fact that Watt's inventions were the results of reasoning based on his knowledge of the laws of Nature, and into them entered no element of chance. Even in his early days he was a student of science, and although not nominally a student at Glasgow University he acquired there a sound and extensive knowledge of the science of his time. His friend, Professor Robson, said of him: "Everything became to him a subject of new and serious study." No words could more clearly describe his temperament or indicate better the secret of his success.

The afternoon of Wednesday was devoted to visits to the three old Watt engines in the Birmingham area. These engines were all constructed for pumping purposes, and the most modern of the three erected 102 years ago in Lawley Street is still in daily use. The second of the engines referred to stands at Bordesley, and was erected in 1796 for the Warwick and Birmingham Canal Company. Though the engine is now derelict it worked continuously from 1796 to 1884, and during that time was under the charge of only two engineers—father and son—its capacity was 140 gallons per stroke and it could do 10 strokes per minute. The most notable of these old engines is that at Ocker Hill. During the afternoon of Wednesday nearly 200 visitors inspected this engine, most of them taking an indicator diagram. One of these diagrams taken on the 18th inst., we, on page 415, reproduce. Those unfamiliar with the peculiarities of the Cornish engine may perhaps have a little difficulty in understanding the diagram. In the Cornish engine live steam is admitted to the top of the cylinder only and an equilibrium valve then establishes communication between the top and bottom of the cylinder. The upper part of the diagram was taken with the indicator connected to the top of the cylinder. The lower portion is the diagram for the other side of the piston. The admission pressure here is the exhaust pressure from the top of the piston, there being no "receiver drop," as occurs in the somewhat analogous case of a compound engine. An assistant of Mr. Willet, the engineer to the Birmingham Canal Company, had prepared an excellent working drawing of the engine.

Perhaps the most notable event of Wednesday, however, was the commemoration dinner held in the evening in the Grosvenor Room of the Grand Hotel. The Lord Mayor (Sir David Brooks) presided. The King's health having been drunk, Sir Oliver Lodge proposed "The Houses of Parliament," pleading for increased support of the work of the Ministers and for the encouragement of scientific research. In replying to the toast, Mr. Austin Chamberlain said that the universities ought to receive more generous treatment in the future than they had in the past. The grants should be increased not merely temporarily to repair the injuries due to the war, but permanently. This would be done as we could afford it. Science must undoubtedly play an increasingly important part in our national life, and should be encouraged accordingly. It would, however, be a mistake to concentrate the control of university education in Government hands in London. He believed in working through the universities which were scattered through the provinces and were supported by the surrounding communities. In fact, the Government would do its share on condition only that the towns did theirs.

Succeeding this came the toast of the Navy, Army and Air Force, proposed by Mr. Gilbert C. Vyle, Treasurer of the Watt Memorial Fund, and responded to on behalf of the Navy by Engineer Vice-Admiral Sir George G. Goodwin, K.C.B., and for the Army and Air Force by Colonel Barraclough, Professor of Mechanical Engineering in Sydney University.

The most notable speech of the evening, however, was that of the American Ambassador (the Hon. J. W. Davis) who in proposing "The City of Birmingham," recalled the fact that the success of the Watt engine in 1776 coincided with the American Revolution, and that the year of Watt's death—1819—saw the arrival in Liverpool of the Savannah, the first steam-driven ship to cross the Atlantic. The life of Watt reminded him of the work of the American pioneers, and but few of the great things that had been accomplished by the last three or four generations would have been achieved if James Watt had not conceived his great invention. He commended the proposed memorial to his countrymen, and hoped they would liberally support the efforts of the committee.

Professor Burstall proposed "The memory of James Watt," which was drunk in silence after a brief eulogy of Watt by Professor Rateau, the eminent French engineer who had been delegated by the French Academy and the Société d'Encouragement l'Industrie Nationale especially to bring to them at the Watt Commemoration a tribute of honour and appreciation from science and labour in France to the memory of the great man in whose honour they were met that day.

The programme for Thursday included a visit to the works of Messrs. Avery (who now occupy the old Soho Foundry of Boulton and Watt) the Degree Congregation and various excursions. At the outset it must be pointed out that Watt was connected with two separate establishments, one the Soho Manufactory, which Boulton built in 1765, and the other the Soho Foundry, erected about thirty years after, when the steam engine business had become successful and more space was required. The Soho Manufactory we illustrated in the Memoir on James Watt, written by Engineer Commander Edgar C. Smith, R.N., and published in our issue of August 22. It was in this building that Watt carried out his experiments on "Beelzebub," "Old Bess," and other engines and the "Manufactory" continued in use by the firm till some time after the death of Watt, when it was deserted and finally demolished. The "Soho Foundry" however, continued to "give birth to many useful arts and inventions." In our visit to Messrs. Avery's we were pointed out the shop in which a "rearing feast" was given in January, 1796, to the engine smiths and all other workmen employed in the erection. On this occasion Boulton made a speech beginning: "I am now, as the father of Soho, to consecrate this place as one of its branches; I also come to give it a name and my benediction. I will, therefore, proceed to purify the walls of it by the sprinkling of wine, and in the name of Vulcan and all the Gods and Goddesses of Fire and Water, I pronounce the name of it Soho Foundry. May that name endure for ever and ever, and let all the people say Amen, amen."

Many of the original Boulton and Watt workshops are still in use, and in the erecting shop is an old wall planer, probably the first wall planer ever built, and a spare screw for the machine has been resting on a shelf close by for the last thirty years ready to replace that in use when needed. Near the entrance to the works are twelve of the cottages, and No. 13 Foundry-row is that occupied by Murdoch till 1817, when he removed to a larger residence, Sycamore House, a short distance away. The office used by Watt still stands, the old coining mint is in use as a smithy and standing in the grounds of the factory is the first gasometer ever built, slowly decaying away. Not the least interesting of sights are the vaulted cellars where it is thought the metal and coinage were stored. They are of considerable extent and, leading from them is a tunnel, which is partly choked with rubbish and of which the course and exit are unknown. Among the staff of Messrs. Avery is Mr. Brown, whose father, grandfather, and great-grandfather have all been connected with the Soho Foundry. He kindly showed us a copy of *The Times* for Saturday, August 28, 1819, which contains the announcement of Watt's death, and in view of the confusion, due to Muirhead and Smiles, that Watt died on August 19 and not on August 25, it may be of interest to quote the announcement referred to, it is as follows:—

"DIED.

"It is with great regret that we communicate to "our readers the death of that distinguished philoso- "pher, James Watt, Esq., on Wednesday, the 25th "inst.; in the 84th year of his age. He was alike "eminent in literature and science and was most "distinguished by his invaluable discoveries in the "improvement of the steam engine, which he "rendered applicate to every purpose of art and "navigation."

Every visitor to the Soho Foundry was presented with a small souvenir book of photographs and a copy of an article on The Romance of the Soho Foundry, which appeared in *The Business Man*, the official organ of the Birmingham Business Club, June, 1919.

The visit to Messrs. Avery was arranged in time for visitors to return to the city to attend the Degree Congregation at 12 o'clock. This was held, not in the University Buildings at Bournbrook, but at the Midland Institute. The recipients of the honorary LL. D. degree were as follows: The American Ambassador, Professor A. C. E. Rateau, Colonel W. C. Blackett, Professor Archibald Barr, Eng. Vice-Admiral Sir G. G. Goodwin, Sir G. T. Beilby and Mr. F. W. Lanchester.

HELL GATE BRIDGE, NEW YORK.

By FRANK W. SKINNER, M.Am.Soc.C.E.

(*Continued from page* 299.)

FABRICATION.

IN May, 1911, the American Bridge Company was notified of the principal requirements for the superstructure, the engineer's plans and specifications were issued, and in November the contract was awarded to the American Bridge Company in competition with the Pennsylvania Steel Company, the McClintic-Marshall Company and the Phœnix Bridge Company.

The American Bridge Company's investigation of the general design resulted in their recommendation of changes in the proposed arrangement of materials in the bottom chords of the arch trusses which obviated splices that would have been difficult to make satisfactorily. The bridge company also arranged with the Pennsylvania Railroad Company for the latter to construct special cars heavy enough to transport the large chord sections from the bridge shop to the site in single pieces complete except for the omission of the large gusset plates. The necessary changes being authorised by the consulting engineer, the bridge company prepared sufficient general drawings and laid out the details to such an extent as warranted the approval of the chief engineer and the ordering of the material, which was accomplished about May, 1912. At this time the final modifications of the specifications, regarding rivets and loading were completed, and the bridge company proceeded to the completion of the detailed plans designed with reference to the erection requirements.

SHOP EQUIPMENT.

The work was fabricated at the Ambridge plant of the American Bridge Company, near Pittsburgh, in the main shop, which is a steel frame structure 776 ft. long, 270 ft. wide including an end transept 330 ft. wide and 130 ft. long, and is equipped with two 40-ton and two 30-ton overhead cranes. It is used as a finishing department in which the planers and boring mills are the only machine tools installed. The shop has a capacity of 10,000 tons per month of heavy structural work, with a force of about 900 men working single shift.

The general arrangement and equipment of the shop provided for a universal longitudinal movement of all materials on four 30-in. full-length surface

tracks which extend into the shipping yards. All transverse movement of materials was effected by 42 overhead cranes of from 5 tons to 40 tons capacity, which run on the lower chords of all the roof trusses, from one to four of these cranes being located in each panel.

Riveting was done by two 100-ton vertically-moving hydraulic machines of 6-ft. gap and 6 ft. lift, and a capacity for driving 1¼-in. rivets with 9-in. grips. There were also vertically-moving 60-ton pneumatic riveting machines of 5-ft. throat. The members, suspended from travelling gantries, were passed through both classes of machines. The 60-ton pneumatic riveting machines were also served by jib wall cranes which handled the cover-plate work. Laying-out, punching, fitting, reaming and riveting were carried on simultaneously and consecutively without involving any backward movement of material. Reaming and drilling was all done by gantry machines operating multiple adjustable drills.

The sizes of the gusset plate were practically up to the limit of capacity of the rolling mills, and unusual care was exercised at the mills to make the plates very straight and accurate, and especially to avoid excessive thickening in the centres of the plates caused by the springing of the long rolls under pressure. Wherever the width of web or cover plates exceeded the width which could be rolled in universal mills, namely, 48 in., the sheared edges were finished by two cuts in the 40-ft. long planing machines.

The specifications provided for punching, or for sub-punching and reaming for plates less than $\frac{5}{8}$ in. thick, but the thickness of the plates was so great that nearly all of the holes were drilled from the solid. Where rivets passed through two or more thickness of plates or metal more than $\frac{5}{8}$ in. thick, the holes were reamed after assembling to a diameter $\frac{1}{16}$ in. greater than that of the rivets. All drilling and reaming was done dry with self-hardening tool steel, and after it was completed the ends of the holes were finished by a special reamer that removed the sharp edges and burrs leaving a fillet $\frac{1}{16}$ in. deep in each rivet head. There are in the whole span about 840,000 shop rivets, most of them 1 in. or 1¼ in. in diameter, driven under hydraulic pressure of about 100 tons and at a maximum rate of 3,500 rivets per day per machine. Where the hydraulic machines could not be used the shop rivets were driven with pneumatic buckers-up and pneumatic riveting hammers with 9-in. stroke.

For the bottom chord members of the arch (see Fig. 39, page 412) the two webs with their flanges were first assembled and riveted separately, and then assembled and riveted to the middle diaphragm, after which the top and bottom cover plates were added. The built I-beams forming the cross sections of the bottom chords and the diagonals were supported at one end by a travelling gantry, and at the other end on a truck, and were thus passed through the hydraulic riveting machines. These pieces had a maximum weight of about 60 tons each, and when assembled together were supported on double 24-in. I-beam skids.

Rivets.

The diameter of the rivets was required to be such that when heated to the proper driving temperature they would not enter the hole without being forced by hammers. When the grip was four times as great as the diameter or more the rivet was tapered so that the base was $\frac{3}{64}$ in. larger and the point $\frac{3}{64}$ in. smaller than the nominal size. Experiments showed that such rivets driven in holes exactly $\frac{1}{16}$ in. larger than the nominal diameter filled the holes more perfectly than ordinary cylindrical rivets, but that allowance had to be made for irregularity in diameter of rivets and holes due to the rapid wear of the rivet dies and drills. Accordingly, 1¼-in. rivets were finally required to have a minimum diameter of $1\frac{9}{32}$ in. under the head, tapered to $1\frac{1}{4}\frac{5}{6}$ in. in a distance of 5 in. to 6 in. from the head depending on the length of the rivet, the rest of the shank being parallel.

Great care was taken in the manufacture of the rivets which, instead of being cut off from the hot rod and completed at one motion, were made from pieces cut to lengths from the cold rod, separately placed in the upsetting machine, and made by at least two strokes, eliminating the fins formed by the dies in a single-stroke process. Any scale that was left on the rivets was removed by rumbling, and if necessary projections were ground off.

Facing Bottom Chord Joints.

The most difficult shop work was the finishing of the ends of the bottom chords so that the very large surfaces should have the required uniform complete bearing at the varying angles. This result was accomplished, and extremely accurate work was done with special facilities and unusual precautions.

The chords were securely clamped on a fixed platform, and both ends were planed to the required angle determined by a transit line giving the plane to which was set a specially-installed horizontal and vertical planer, mounted on a rotary platform, and having a cutting range of 12½ ft. horizontally and 10½ ft. vertically. The centre lengths of the members were accurate within $\frac{1}{64}$ in., and the bevels of the bases were accurate within 30 seconds, equal to $\frac{1}{64}$ in. in 10 ft. The planing machine had a fixed bed, 70 ft. long, and a revolving head, both mounted on massive concrete foundations. The base of the revolving head was 18 ft. in diameter and was graduated to 4 minutes enabling it to be set at any required angle with the piece bolted on the stationary bed.

All of the chord sections were first bolted to the platform with their webs in horizontal planes, and a vertical roughing cut of $\frac{1}{2}$ in. to $\frac{7}{8}$ in. was made on the vertical diaphragm by two cutting tools arranged so that one cut on the forward stroke and the other cut on the return stroke, thus avoiding loss of time and making the cutting operation continuous. After the roughing cuts were completed the cutting tools were turned 90 deg. and corresponding horizontal cuts were taken on the main web after which the vertical finishing cuts of from $\frac{1}{16}$ in. to $\frac{1}{32}$ in. were made across the entire end of the piece, both tools operating together as before to cut on both forward and return strokes. The two cuts for the ends of one chord were made in about 12 hours. After one end was finished the yard gantry removed a portion of the horizontally-sliding roof of the steel building in which the planing machine was installed, lifted out the chord member, and reversed it for the other end to be planed. In both trusses there were a total of 184 chord joints to be finished.

After both ends of the pieces were planed to the proper length and successive sections of the chord were assembled temporarily on the skids at the bridge shop yard, and after the accuracy of the joint had been established, the pieces were returned to the planing machine and the outer thirds of the surface on one end of each chord were removed to give it the taper required to concentrate the bearing on one-third of the end of the adjacent section of chords.

Both ends of all floor beams and stringers were simultaneously faced by a double-headed 16-in. rotary planing machine that insured absolute uniformity of length for all pieces finished at the same setting of the machine.

The efficiency of the drilling and riveting operations was verified by assembling a number of experimental plates having a combined thickness of 7 in. Through them one hundred $1\frac{1}{16}$ in. holes were drilled at different rates of speed. Some of the holes were filled with rivets driven by hydraulic machines, and the others were filled with rivets driven by pneumatic hammers. Sections were then cut through the rivets and both types of rivets were found to fill the holes completely and to be satisfactory.

Yard Assembling of Trusses.

Special heavy skids were provided in the bridge shop yard and had grillage foundations distributing their loads sufficiently to prevent serious settlement under the great weight of the truss members. On these skids all of the members of the two trusses were assembled in a horizontal plane in four-panel sections (see Figs. 35 and 36, page 312 *ante*), the last panel of each section remaining in place while the other three panels were removed, and three new panels were built on until the entire truss had been assembled. Each truss section was laid out carefully in the yard to the correct cambered form by means of transit lines, levels were taken daily and the transit lines checked to assure the correct position of the pieces which were handled by a special gantry crane of 130 ft. span and 150 tons capacity, which was equipped with two 75-ton trolley hoists and two 10-ton auxiliary hoists. This electric crane travelled on reinforced concrete stringers supported on concrete piles driven through the cinder fill of the storage yard, and was used not only for assembling the trusses but for handling, storing and shipping the truss members and other parts of the bridge.

The trusses were assembled in accordance with special diagrams giving the lengths, angles and offsets required. The level was adjusted within $\frac{1}{32}$ in. by thin steel shims and the joints matched without visible imperfection.

All field rivet holes, $\frac{11}{16}$ in. in diameter, were filled with $\frac{5}{8}$-in. service bolts, and after the truss sections were assembled the service bolts were successively removed and the holes immediately reamed out to the required size by long-shank high-speed, unlubricated twist drills, operated by four portable electric reaming machines, with 8-ft. radial arms, that could be set in either horizontal or vertical positions. As fast as the holes were reamed they were filled with larger size service bolts, thus keeping the members always tightly fastened in position. Before the members were taken apart the field connections were match-marked and the marks recorded on a chart for the use of the field force.

The type of yoke used for handling a bottom chord section in the bridge shop yard is shown in Fig. 39, on page 412.

Special steel cars (Fig. 40, page 412), with a capacity of 150,000 lb. each and a length of 40 ft. were built by the railroad company for the transportation of the heaviest members, each of which was loaded with swivel bearings on two cars.

Erection Plant.

The erection of 19,000 tons of steel containing many large pieces, some of them weighing 185 tons, and the hoisting to a height of 320 ft. above a tidal stream with a maximum current of 10 knots an hour navigated by a large number of all kinds of craft, was an unprecedented proposition and was carefully considered in the design of the superstructure. Preliminary study showed the feasibility of cantilever erection, and two alternative schemes outlined by the chief engineer, accompanied the original designs on which bids were invited. One of these systems contemplated the cantilever erection of the arch trusses with eyebar backstays and the use of stringers from the permanent structure for struts and other secondary members. The other system contemplated the erection of the end panels of the arch trusses and falsework, and the erection of the centre panels as cantilevers supported by backstays. In both systems temporary use of permanent bridge members was contemplated for the construction of the backstay system.

The contractor investigated both of the suggested systems, and eventually discarded the falsework system on account of the difficulty of driving piles and because of objections by the Federal Government to the obstruction of any part of the channel by falsework. Continued study and investigation resulted in the development of a backstay system in which the costly eyebars were eliminated and 85 per cent. of the steel required was borrowed from the permanent structure and afterwards used therein. All of the falsework was eliminated, and details were developed for the use of the plate girders from the approach viaducts for the main tension members of the backstays and for the use of members in the main arch, for other portions of the temporary structure so that, although its total weight of steel was considerably increased over the engineer's estimate because the contractor preferred to limit the working stresses to amounts below what had been permitted, on account of the difficulty of some of the connections, the total result was an economy that was believed to be an important consideration in the award of the contract.

Backstays.

The backstays are shown in course of erection in Figs. 41, 42 and 43, Plate XXI. In Fig. 41 the part of the backstay on the Long Island side of the bridge is being erected. Fig. 42 is another view of the same backstay, the two travellers are in

operation, one handling the material for the backstays and the other for the panels of the main arch; the special bridge for the use of the workmen engaged upon the erection will be seen suspended from the bottom chords. In Fig. 43 the completed backstay is shown, and the arch trusses are being erected beyond the backstay connection.

The backstays were substantially alike on both sides of the river, and were somewhat complicated structures on account of their great dimensions, necessitating the intermediate support of long members, the necessity of providing for horizontal struts as well as for direct tension and the development of two successive systems of backstays for the first and second portions of the erection.

As the conditions at the site did not provide satisfactory natural anchorages for the backstays, it was necessary to provide for the reactions thereby, approximately horizontal struts transferring the horizontal components of stress to the bases of the massive piers and by counterweights sufficient for the vertical components. Backstay structures, therefore, became substantially triangular trusses with inclined top chord members intermediately supported on vertical rocker bents at the piers, with horizontal bottom compression chords at the surface of the ground counterweighted with heavy ballast, Fig. 44, on Plate XXI, at the shore ends, and with intermediate vertical supports to prevent undue deflection of the top chords in order to secure more economical dimensions and stresses.

The total weight of steel in the backstays amounted to 15,500 tons, all but 2,300 tons of which were utilised in the permanent structure. The backstays supported 14,500 tons of arch weight that developed a maximum pull of 6,500 tons in each backstay and was resisted by maximum counterweight of 5,300 tons on each side of the river. The backstays were proportioned for maximum stresses from all erection operations, for dead load and live-load stresses, for stresses developed by the traveller and other erection equipment, and by a wind pressure of 30 lb. per square foot of exposed area, and were so proportioned that the unit stresses from all of these sources did not exceed 20,000 lb. per square inch. Of the 15 per cent. of the erection material that was not used in the permanent structure about 120,000 lb. consisted of cast-iron and cast steel hydraulic jacks and other tools, and the remainder was of a nature not much mutilated by fabrication for the erection purposes so that most of it was eventually returned to stock.

There were four backstays, one at each end of each arch truss, extending in the plane of the truss to a distance of nearly 480 ft. beyond the skewback, at which point there was centred a counterweight. The total height of the backstays was about 290 ft. above the surface of the ground or about 320 ft. above high water-level.

The principal member of each backstay was the inclined top chord, made up of two lines of plate girders, 9 ft. deep, 90 ft. long and 6½ ft. apart on centres, with an aggregate net cross-section of 316 sq. in. This top chord was at first made in two sections supported near the middle point on a vertical post and attached at the river end to the top chord of the arch truss. After the arch truss was built out to panel point 11, about half-way from the skewback to the crown, the river end of the backstay was elevated so that it was in line with the shore end, and was supported on a massive braced vertical tower seated on top of the unfinished masonry pier, and from this point it was connected to the top chord of the arch truss at point 11, by a second section inclined downward from the pier, which was made up of three lines of floor suspenders from the arch span with eyebar links, pin-connected to a movable shoe on top of the pier tower.

The horizontal bottom chord acting as a strut between the anchorage and the main pier was composed of four lines of floor stringers braced together laterally and supported on timber grillages, and had a maximum section of 290 sq. in.

The vertical tower, Fig. 43, on the pier, was made up of four lines of viaduct girders and their bracing, and had a cross-sectional area of 348 sq. in. The main intermediate vertical where the upper and lower top chords intersected, was made up of two lines of plate girder stringers with their transverse bracings, and had a roller bearing at the top to support the top chords and permit their longitudinal movements. The intermediate vertical posts supporting the top chords of the backstays were made of stringers from the floor system of the arch span, and were provided with special end fittings. They were braced together in pairs with horizontal and diagonal members forming independently stable falsework towers.

The shore ends of the backstay trusses rested on large timber grillage foundations distributing their heavy loads over the ground. At the Long Island end the counterweight consisted of three crossed tiers of plate girders and a quantity of earth from the excavation, which as the erection progressed, was gradually filled in on top of the second tier in a space enclosed by the third tier of girders to form the sand-box. At the opposite end of the span the counterweight, Fig. 44, was similar except that as there was not sufficient earth provided by the excavation the additional weight was made up by I-beams borrowed from the floor system. The lattice girder for the side walks, 12 ft. 4 in. deep, which also forms the hand rails, were used for working platforms and for bracing between the vertical posts in the falsework towers. The pins in the permanent connection between the floor beams and the arch hangers were temporarily used for connecting river ends of the top chords of the backstays. The pins forming the permanent bearings of the plate girders in the viaduct were used for expansion rollers at the top and bottom of the intermediate vertical posts and under the counterweights. Cast steel shoes supporting the ends of the viaduct girders were used as pedestals for the rocker posts.

Temperature movement in the backstay trusses was provided for by roller bearings under the counterweights and settlement in the grillage foundations was compensated by 500-ton hydraulic jacks, four under each truss having been previously served to measure the weight of the earth fill, which was gradually applied as the arch was erected, and the stresses increased.

The development of the erection scheme was commenced when the preliminary designs indicated that the plate girders in the approach spans would have square ends and would be seated on separate pedestals on top of the masonry piers. This feature lent itself readily to the details for the tension connections of the girders, end to end, in the backstay chords. The girders were temporarily lengthened, and the unit erection stresses were reduced to 20,000 lb. per square inch.

The dimensions of the plate girders varied somewhat, but were generally about 90 ft. long by 9 ft. deep, and they weighed about 35 tons each. The girders were at first detailed in accordance with the requirements for their permanent service in the viaduct, after which they were lengthened sufficiently to permit the addition of temporary splices for erection purposes, care being taken that the body of the girder was qualified for the abnormal stresses developed during erection. The webs and flanges of the girders were extended sufficiently to receive the double cover splice plates that were connected to them in some cases with bolts, in some cases with rivets, and in some cases with drift-pin bolts, according to circumstances and requirements. The great lengths of the girders were advantageous, in that they required less intermediate tower support than would eyebar members. After the completion of the arch erection and the taking down of the backstay trusses the projecting ends of the girders were burned off with oxy-acetylene torches, leaving the girders ready for erection in the approach viaducts.

The most difficult detail in the backstay structure was the connection under the counterweight between the top and bottom chords of the backstay. Here two large inclined girders from the top chord of the backstay were connected to four horizontal stringers in the lower chord, both sets being spaced 6½ ft. apart, a dimension which it was desirable to maintain on account of the transverse bracing connecting them. After considerable study a satisfactory detail was developed with gusset plates 10 ft. or 12 ft. wide and an elaborate system of diaphragms and connection plates that distributed and transferred the high stresses. All of the designing in the backstay system was so carefully done that little new material had to be purchased except for connections.

(To be continued.)

MOULDING-SANDS FOR NON-FERROUS FOUNDRY WORK.*

By P. G. H. BOSWELL, D.Sc., F.G.S., Professor of Geology in the University of Liverpool.

Introduction.—The technique of casting non-ferrous metals and alloys carries with it problems peculiar to itself. The difficulties that have arisen in works' practice have, for the greater part, been solved empirically—often by the safe but lengthy and expensive method of trial and error. So far as can be gathered from available literature, there seems to have been little scientific investigation into the difficulties which are sometimes met within non-ferrous moulding-sand practice, although the very different effects on the structural strength and physical properties of castings made in sand and metal ("chill" castings) have been carefully worked out and recorded.†

After observing moulding-sand practice in numerous foundries at home and abroad, the writer feels that, as in the case of many of the problems arising in steel practice, but to an even greater extent, the success achieved in non-ferrous founding is more dependent upon the individual skill of the moulder or foreman than upon the application of scientific knowledge.

It may be desirable to amplify this statement to some extent. Steel is frequently cast at a temperature above 1,600 deg. C., and sometimes (when made in converters) above 1,650 deg. C. Such temperatures may be higher than the softening point, and well above the inversion points, of silica, which, as the mineral quartz, constitutes 80 per cent. or more of moulding-sands. The other constituents of moulding-sands (such as clay) fuse at lower temperatures. The elimination of one of the most serious evils in steel-casting, that of "burning on," is therefore at present an unsolved problem, essentially scientific in character. In good foundry practice the trouble may be reduced, but it has never yet been entirely eradicated. The results that are produced vary, too, with the composition of the steel and the physical characters of the sand, both matters amenable to scientific control.

On the other hand, both iron and non-ferrous metals and alloys are "run" at much lower temperatures, which rarely exceed 1,300 deg. C. Most sands, when subjected to these temperatures for a limited period of time, remain essentially unchanged. The task of obtaining good sound castings in iron, brass, bronze, aluminium, &c., is rather one dependent upon skilful moulding technique than upon the chemical characteristics of the sand. Nevertheless, the investigation of the texture and physical properties of the moulding-sand used does lead to results of practical value.

Whilst the problems concerned with casting non-ferrous metals and alloys in sand are generally less difficult, on account of the lower temperatures involved, than those concerned with steel, the former carry with them certain peculiar difficulties which result from their increased tendency to oxidation, more ready vaporisation, greater mobility and greater sand-penetrating power. These peculiarities make cast-iron a much easier material to found.

As an illustration of these difficulties, it may be remembered that, despite the fact that the casting temperatures of a metal like lead or an alloy such as phosphor-bronze are comparatively low, the skin of the castings may be rough or veined on account of the penetrating ("searching") power of the molten material or the "burning on" of the sand. The production of semi-fused sand intimately mingled with the surface layers of the metal cannot always be definitely prevented. The problem is not an easy one to solve, for "burning on" may result during the casting of lead at a temperature of less than 800 deg. C., whilst it is usually absent during the casting of manganese-steel at a temperature reaching approximately 1,600 deg. C. That chemical affinity alone is not involved is clear from the fact that glassy silicates of manganese are readily produced at the surface of the mould; fortunately the greenish "glass" adheres to the sand, and not to the metal of the casting. It seems that, having only the present data in hand, we can do no more than speculate, and until we succeed in obtaining the facts that indicate the relation of the behaviour of metals and alloys during casting to their physical and chemical characters, the uncertainty will remain.

This peculiar behaviour of metals and alloys has, however, been countered to some extent empirically, as a result of works, experience, by paying due regard to the composition of the moulding-sand used. Penetration of the sand by very mobile metal may be prevented by using sands of finer grain and "closer" band than those employed in steel or iron founding, and by ramming them more tightly. The venting and permeability of the sand to gases and vapours is in part voluntarily sacrificed, a course of action which doubly necessitates the complete "killing" of the metal before it is cast. Indeed, the moulding practice is deliberately framed to prevent the sucking in of air through the pores of the mould (particularly at the top) during the contraction of the metal. At the same time, it is doubtful whether "blow-holes" in the metal are produced, as it is some-

* Paper read before the Institute of Metals, September, 1919.

† See, for example, "Alloys and their Industrial Applications," E. F. Law (London, 1917), page, 259, &c.

TABLE I.—CHEMICAL ANALYSIS OF NON-FERROUS MOULDING-SANDS. PERCENTAGE WEIGHTS.

—	SiO_2.	Al_2O_3.	Fe_2O_3	FeO.	MgO.	CaO.	Na·O	K_2O.	H_2O+	H_2O-	CO_2.	TiO_2.	ZrO_2.	P_2O_5.	SO_3.	Cl.	MnO.	BaO.	Total, &c.
A. BUNTER SANDS.																			
Belfast, Knockvale	81·47	8·84	1·84		0·81	0·86	1·50	2·78	loss on ign 2·24			0·35	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·69
Belfast, Lagan Vale	74·80	7·70	1·13	0·56	1·33	4·55	1·34	2·65	1·18	0·50	3·52	0·30	n.d.	0·04	0·02	trace	0·04	0·04	99·70
Birmingham, Hockley Cemetery, close	84·86	6·69	1·08	0·35	0·43	0·29	0·40	3·41	1·21	0·55	none	0·40	trace	0·09	none	trace	0·01	0·04	99·81
Compton, near Wolverhampton (bulk)	86·37	6·40	0·96	0·25	0·42	0·26	0·36	3·25	1·00	0·57	none	0·35	trace	0·06	none	trace	0·01	0·04	100·30
Compton, medium-sand grade (MS.)	94·37	2·82	0·46		0·17	0·16	0·12	1·57	loss on ign. 0·48			0·06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·21
Compton, fine-sand grade (FS.)	89·10	5·32	0·88		0·28	0·24	0·15	3·13	0·71			0·21	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·02
Compton, coarse-silt grade (cs.)	85·31	6·95	1·23	0·22	0·37	0·41	0·49	3·31	1·43			0·43	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·15
Compton, fine-silt grade (fs.)	69·05	14·15	2·70	0·53	1·05	1·27	0·56	5·45	4·28			0·97	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·01
Compton, clay grade (c.)	58·17	19·58	5·47	0·55	1·78	1·34	0·38	5·37	6·34			0·73	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·71
Heck, near Selby	87·14	5·89	1·00	0·29	0·41	0·25	0·14	2·95	1·00	0·55	none	0·18	0·02	0·08	0·03	trace	0·02	0·03	99·98
Kidderminster Station Pit	85·66	6·59	0·86	0·36	0·55	0·26	0·16	3·41	1·22	0·74	none	0·40	trace	0·10	none	trace	0·01	0·03	100·35
Mansfield, upper sand	88·60	5·40	1·08	0·22	0·28	0·18	0·06	2·49	1·06	0·28	none	0·19	n.d.	none	trace	trace	0·02	0·01	99·87
Mansfield, lower medium	82·51	4·96	0·97	0·30	1·56	2·39	0·10	2·20	1·29	0·47	2·92	0·17	n.d.	0·07	none	trace	0·02	trace	99·93
Ormskirk, Aughton Park	92·30	3·94	0·34	0·15	0·16	0·12	0·03	2·14	0·56	0·34	n.d.	0·19	n.d	trace	n.d.	trace	trace	0·02	100·29
Red Bay, Antrim	79·88	8·42	1·61	0·22	1·13	0·41	0·22	3·91	1·75	1·87	0·04	0·35	n.d.	0·10	none	trace	0·02	0·02	99·95
Stourbridge	85·64	6·48	0·94	0·46	0·43	0·38	0·32	3·20	1·06	0·81	none	0·28	n.d.	0·08	none	trace	0·01	0·02	100·11
Wombourne, Staffs.	83·84	7·28	1·44	0·23	0·52	0·31	0·26	3·43	1·46	0·96	none	0·32	n.d	0·15	none	0·02	trace	trace	100·22
Worksop, best medium	88·89	5·37	0·72	0·30	0·39	0·19	0·07	2·46	0·97	0·40	none	0·16	n.d.	0·03	none	0·02	trace	trace	99·97
B. OTHER SANDS.																			
Carboniferous—																			
Avenuehead, N.B.	80·70	7·86	3·06	und.	0·77	0·68	0·07	1·55	2·19	1·47	none; organic carbon 0·13	0·48	n.d.	0·10	none	0·03	trace	0·02	99·70
Estuarine Series (Jurassic)—																			
Huttons Ambo	90·30	4·51	1·02	0·21	0·23	0·15	0·12	0·75	1·72	0·52	none	0·31	n.d.	trace	none	trace	trace	trace	99·84
Kelloway Beds (Jurassic)—																			
South Cave, lower yellow sand	94·80	2·93	0·13	n.d.	trace	0·14	0·22	1·42	loss on ign. 0·47			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·11
Eocene—																			
"Erith" sand, "strong"	83·89	5·38	2·31	0·18	0·58	0·49	0·04	2·20	2·07	2·11	none; organic carbon 0·09	0·36	n.d.	0·06	0·42	trace	trace	trace	100·18
"Erith" sand, "mild"	86·53	4·67	2·16	0·20	0·45	0·28	0·42	1·84	1·51	1·53	none	0·36	n.d.	0·04	none	trace	trace	trace	99·99
Doubtful Age—																			
Barrow-in-Furness (bulk)	87·03	7·11	0·80	0·16	0·43	0·26	0·07	1·76	1·78	0·45	0·15	0·25	n.d.	none	n.d.	trace	0·20	trace	100·36
Barrow-in-Furnace CS.+MS. fraction	95·56	2·03	0·54	n.d.	0·17	0·20	0·12	0·50	loss on ign. 0·82			0·08	n.d.	n.d.	n.d	n.d.	n.d.	n.d.	100·02
Barrow-in-Furness FS. fraction	94·57	2·66	0·71	n.d.	0·23	0·18	0·12	0·76	loss on ign. 0·80			0·19	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·22
Barrow-in-Furness cs. fraction	88·92	5·60	0·71	0·20	0·43	0·14	0·16	1·92	loss on ign. 1·54			0·49	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·11
Barrow-in-Furness fs. fraction	76·37	11·77	1·94	0·44	0·66	0·45	0·13	3·81	loss on ign. 3·53			0·89	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·99
Barrow-in-Furness c. fraction	49·97	24·81	3·67	0·48	1·56	3·15	0·21	5·44	loss on ign. 10·30			0·26	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·85
Glacial—																			
"Lancashire loam," Oldham	85·56	6·01	2·26	undet.	0·33	0·38	0·67	2·12	1·28	0·44	none; organic carbon 0·71	0·40	n.d.	0·11	none	trace	0·05	0·02	100·34
Durham "strong"	78·29	8·70	4·14	undet.	0·50	0·16	0·65	1·46	3·18	1·00	none; organic carbon 0·99	0·60	n.d.	0·08	none	trace	0·06	0·03	99·84
C. STEEL-MOULDING SAND FOR COMPARISON.																			
St. Erth, "Cornish Red" sand—																			
(Bulk)	86·11	5·29	2·45	0·29	0·47	0·40	none	0·95	2·26	1·31	none	0·34	trace (0·007)	0·08	0·20	none	trace (0·005)	none	100·15
FS. fraction	96·73	1·04	0·50	n.d.	0·13	0·26	0·08	0·38	loss on ign. 0·63			0·14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·89
cs. fraction	92·07	3·02	1·25	0·20	0·17	0·38	0·09	0·89	loss on ign. 1·21			0·42	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·70
fs. fraction	55·34	18·87	9·85	0·47	1·27	0·95	0·18	2·02	loss on ign. 10·14			0·85	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99·94
c fraction	46·67	20·78	12·89	0·41	1·52	2·27	0·40	2·29	loss on ign. 12·29			0·85	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100·37

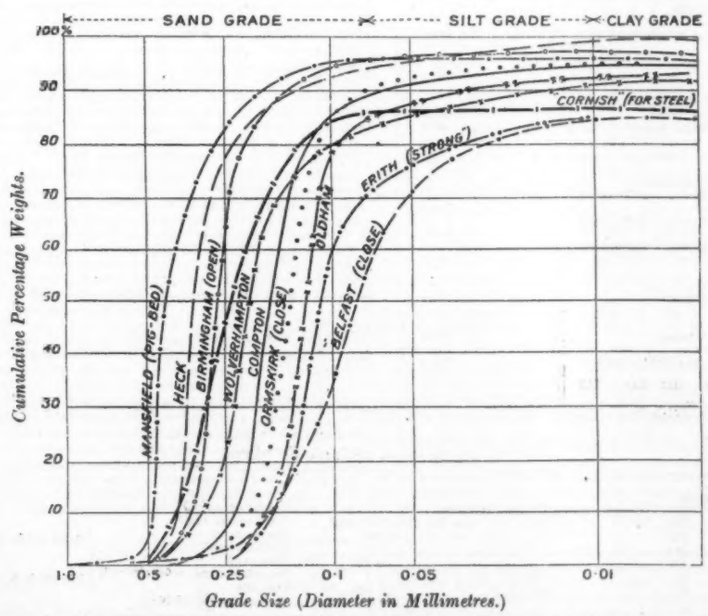


FIG. 1. MECHANICAL ANALYSES OF MOULDING-SANDS; GRAPHICAL REPRESENTATION.

times claimed, by air entrapped in this way. The more probable explanation lies in the incomplete freeing of the metal from gases before casting.

Even supposing that many of the problems of non-ferrous foundry work are as yet unsolved, it may still be desirable to record the chief moulding-sands in use in Britain for non-ferrous work, and to give their chemical and mechanical composition. Iron- and brass-moulding sands appear, in chemical and physical characters, to be much the same all the world over; steel-moulding sands differ considerably from each other.

The sands used in British non-ferrous foundry practice may be conveniently divided into (*a*) the red sands from the deposits of Bunter (Triassic) age, occurring along a well-marked belt throughout England (see tables and Fig. 3), and at a few isolated localities in Scotland and Ireland; and (*b*) various other grey, yellow, or brown sands, of different geological ages, scattered widely over the country.

Laboratory Investigation of Moulding-Sands.—The fact which strikes the investigator most in his research into foundry sands is the absence of reliable fundamental data. No correlation of the behaviour of the sands or metals or of the results attained in casting can therefore be made. The accumulation of the necessary empirical information is too big a task for a single foundry or an individual investigator. It should rather be carried out by some organisation such as the National Physical Laboratory, or better, the proposed research institution to be known as the Petrophysical Institute. Work of the character desired has been begun in the United States of America (where foundry technique is less advanced than at home) at the Bureau of Standards, and the results of some useful work have been published.*

The testing of sands in the laboratory is necessarily of a preliminary character only, and must be correlated with the results of actual practice in the works, where the final tests should be made. Laboratory investigation, involving the methods of both pure and applied science, cannot be dispensed with; there are too many unexplained and unexpected happenings in even the best regulated foundries to permit the ruling out of pure scientific research. The laboratory testing of moulding-sands may be carried out along the following lines:—

1. Chemical analysis. 2. Mechanical analysis. 3. Mineral analysis. 4. Character and composition of the "bond"; colloidal or otherwise. 5. Compressive strength of sand-moulds and cores. 6. Transverse strength of sand-moulds and cores. 7. Tensile strength of sand-moulds and cores. 8. Thermal conductivity of moulding-sands. 9. Permeability. 10. Porosity.

* Transactions of the American Foundrymen's Association, 1912, page 19, &c.

Adequate knowledge of the inter-relation of the properties of suitable sands as revealed by investigation along the above lines cannot fail to lead to the standardising of results and the elimination of haphazard methods. Some indication of what may be done in this way can be gathered from the above-mentioned accounts of tests carried out at the United States Bureau of Standards.

The results obtained in works' trials should be correlated with the chemical and mechanical composition and the physical properties (specific heat, thermal conductivity, latent heat of fusion, &c.) of the alloys and metals concerned, as well as with the temperatures at which they are cast. No information on these comparative lines is yet available, and some years must elapse before it can be accumulated. However, the excellent quality of British moulding-sands and the pre-eminent skill of the British foundryman are the strongest arguments which can be adduced for the further improvement and standardisation of the output of our foundries.

Chemical Composition.—When it is realised that many of the published records of chemical analyses are inaccurate and valueless, it is perhaps not surprising that such analyses are held in little esteem by foundrymen. The older published analyses in particular are unreliable. The precautions necessary to be taken in the carrying out of silicate analysis were unknown or unpractised. (It may be claimed, and perhaps with reason, that accurate methods of silicate analysis have been in vogue only within the last twenty years.) To take the case of one of the most important constituents of moulding-sands, the quantity of iron oxide recorded in the old analyses of well-known sands is noteworthy as being five or six times too great. Modern analysis of many of the sands with a previously recorded iron percentage (as Fe_2O_3) of 6 per cent. or 7 per cent. are given in Table I. A brief account of precautions to be taken in making chemical analyses of sands is given by the writer in a general publication on refractory sands,* further particulars of which are given in the Appendix to this paper.

On page 419 it was observed that British sands used for non-ferrous work could be divided into two well-marked classes. One class, the Bunter sands, contains materials of the same geological age from different localities; such sands, therefore, show somewhat similar composition and properties. The other class, consisting of sands from various geological horizons, shows little uniformity in its constituents. In Table I are given the results of chemical analyses of sands from both groups, kindly carried out by Dr. H. F. Harwood, of the Chemical Department of the Imperial College of Science and Technology.

Mechanical Composition.—The fact that sands from either of the above classes yield equally good results in casting emphasises the contention that in all foundry work the texture, or mechanical composition, of the sand is of great importance, and that in non-ferrous practice it becomes supreme. Mechanical analyses are made in order that the observer may determine the sizes of the grains present, and the relative weight of each portion between certain agreed limits of size ("grades").

The grading adopted by the writer is annexed.

The gravel and coarser sand-grades in a moulding-sand may be estimated by screening, but it is obvious that the finer grades, down to clay, cannot be so separated on account of the difficulty experienced in manufacturing accurate sieves of very small mesh. Fine grades in sediments are separated by water-currents of suitably adjusted velocity, the process being known as elutriation, and the method adopted being described in the memoir quoted above.†

Moulding-sands are said to be "strong" or "weak," "fat" or "lean," "close" or "open," according to the quantity and character of the grades present. An "open" or "weak" sand is one consisting largely of the coarse and medium sand grades with very little fine clayey material. When a considerable proportion of clay-grade is present, the sand grains are bound together by clay films, and the material is said to be "strong." The presence of finer grades in a moulding-sand decreases its permeability to water and gases, and such a sand is said to be "close."

The sands used for non-ferrous casting are closer and finer grained than those employed in steel-founding, where, although the bond is required to be strong, the sand must be exceptionally well vented to permit the escape of gases and vapours produced at the high temperatures which are reached.

Steel-moulding sands of the best quality possess a peculiar and characteristic mechanical composition, marked by the high proportion of coarse and medium sand grades, the relatively high proportion of clay-grade, and the low proportion or absence of the fine-sand and silt grades (see the analysis quoted in Table II and Fig. 1). The clay-grade exists as a film round each of the coarser grains, and by virtue of its power of taking up water acts as bond; the fine-sand and silt grades would, if they were present, reduce the permeability of the sand by packing up the pore-space, thus causing blowholes, scabs, &c., in the steel casting.

In the founding of brass, bronze and other alloys, the sand is required to be moderately close, partly in order that a smooth, clean skin may be yielded, and partly to prevent the penetration of the sand by the metal (and the formation of blowholes by the indrawing of air on its contraction). The temperature during casting being lower than that of steel, the mould does not require, if the metal is properly killed, to be so thoroughly vented. Not only is it prepared from closer, sand (without the addition of silica sand to open it up, as in ferrous practice), but it is also more tightly rammed.

The following list (Table II) of mechanical analyses of sand used for non-ferrous work includes also that of a well-known steel-moulding sand, which has been added for comparison. It should be stated that the sands from Park Mine, Barrow, and Avenuehead, N.B., are essentially steel-founding sands, although they are used to a limited extent for casting phosphor-bronze, brass, &c.

(To be continued.

TABLE II.—MECHANICAL ANALYSES OF NON-FERROUS MOULDING-SANDS. PERCENTAGE WEIGHTS.

Locality.	VCS. >1 mm.	CS. >0·5 & <1 mm.	MS. >0·25 & <0·5.	FS. >0·1 & <0·25.	cs. >0·05 & <0·1.	fs. >0·01 & <0·05.	c. <0·01.	S. Total Sand Grade >0·1 mm.
A. RED BUNTER SANDS.								
Armthorpe, near Doncaster	—	2·7	70·6	24·0	0·9	0·4	1·4	97·3
Aughton Park, near Ormskirk (open)	—	—	18·0	68·5	0·5	8·7	4·3	86·5
Aughton Park, near Ormskirk (close)	—	trace	4·3	77·8	12·6		5·3	82·1
Belfast, Knockvale (open)	—	0·4	16·6	39·8	26·9	11·2	5·1	56·8
Belfast, Knockvale (close)	—	0·4	3·0	30·9	50·2		15·5	34·3
Belfast, Lagan Vale	—	0·7	55·5	38·3	1·4	1·2	2·9	94·5
Birmingham, Hockley (open)	—	0·2	67·1	28·0	1·6		3·1	95·3
Birmingham, Hockley (close)	—	1·8	40·6	46·0	6·5		5·1	88·4
Budleigh Salterton, Devon	—	0·6	81·3	11·5	1·5		5·1	93·4
Burghwallis, near Doncaster	—	—	7·1	62·8	20·3	5·7	4·1	69·9
Carlisle, How Mill	—	1·3	9·4	68·9	5·0	4·8	10·6	79·6
Compton, near Wolverhampton (Boot's Quarry)	—	—	6·6	78·1	8·1	1·9	5·3	84·7
Compton, near Wolverhampton (W. J. Lowe's Quarry)	—	0·2	6·5	77·7	7·1	3·2	5·3	84·4
Heck, near Selby (before milling)	—	0·2	77·0	14·7	8·8		0·3	91·9
Heck, near Selby (after milling)	—	0·4	60·7	14·0	7·2		7·7	85·1
Hempshill, near Nottingham (open)	—	1·4	52·9	35·9	3·2		6·6	90·2
Hempshill, near Nottingham (close)	—	0·7	22·7	53·9	13·7		9·0	77·3
Hensall, near Selby	—	1·3	85·1	11·1	0·6		1·9	97·5
Hill Chorlton, Staffs.	—	0·6	52·3	44·3	0·6		2·2	97·2
Kidderminster, Station Yard Pit	—	—	32·4	59·0	0·9	0·8	6·9	91·4
Kidderminster, G.W.R. cutting	—	trace	33·5	51·8	7·8	4·0	2·9	85·3
Lenton, Nottingham	—	0·9	48·0	36·3	5·1		9·7	85·2
Mansfield (open)	sifted to 1 mm.	4·4	78·8	11·4	0·3	0·9	4·2	94·6
Mansfield (medium, before milling)	—	7·5	9·2	74·8	3·9		4·6	91·5
Mansfield (medium, after milling)	4·7	4·1	33·3	37·5	6·8		13·6	79·6
Nottingham, Bobber's Mill	—	1·2	33·8	53·9	6·7		4·4	88·9
Red Bay, County Antrim	—	trace	12·8	30·6	44·0	11·8	0·8	43·4
Runcorn	—	1·4	0·7	72·8	19·7		5·4	74·9
Ruthin, Denbighshire	—	—	—	—	—		—	—
Sedgley, near Wolverhampton	—	0·2	4·4	31·1	55·9		8·4	35·7
Stourbridge	—	0·5	42·3	51·2	2·0	1·5	2·5	94·0
Stourport	—	trace	24·1	68·1	0·9	2·9	4·0	92·2
Whitley Bridge, near Selby	—	1·3	71·8	19·1	1·3		6·5	92·2
Wolverhampton, Gorsebrook (before milling)	—	few grains	27·8	64·6	1·7	1·0	4·9	92·4
Wolverhampton, Gorsebrook (after milling)	—	0·2	20·0	59·5	4·6	7·6	8·1	79·7
Wombourne, near Wolverhampton	—	—	0·8	88·4	3·2		7·6	89·2
Worksop (finest)	—	—	mica only	37·5	31·8	21·0	9·7	37·5
Worksop (fine)	—	0·3	22·5	67·4	2·4	2·4	5·0	90·2
Worksop (pot sand)	—	16·8	76·2	4·2	0·6		2·2	97·2
B. OTHER SANDS.								
Carboniferous—								
Avenuehead, Glenboig, N.B.	—	trace	47·7	39·2	0·8	3·9	8·4	86·9
Permian—								
Pontefract	—	4·1	45·3	33·6	2·3	4·7	10·0	83·0
Estuarine Series (Jurassic)—								
Commondale, Yorks.	—	10·5	11·7	62·7	1·2	7·0	6·9	84·9
Huttons Ambo, Yorks.	—	0·4	16·1	72·0	0·2	0·3	11·0	88·5
South Cave, Yorks.	—	—	8·3	9·02	0·7		0·8	98·5
Thanet Beds (Eocene)—								
Charlton (Kent), "Erith sand," "strong"	—	trace	1·2	60·2	14·2	9·0	15·4	61·4
Charlton (Kent), "Erith sand," "mild"	—	trace	1·3	87·5	2·7	4·0	4·5	88·8
Charlton (Kent), "Erith sand" "loam"	—	0·3	11·2	50·3	9·6		28·6	61·8
Doubtful age—								
Barrow-in-Furness	—	5·5	39·6	32·6	0·2	6·2	15·9	77·7
Glacial—								
Durham, "strong"	—	trace	3·7	63·4	8·2	15·6	9·1	67·1
Oldham, "Lancashire loam"	—	trace	0·2	79·1	13·7		7·0	79·3
C. STEEL-MOULDING SAND FOR COMPARISON.								
St. Erth, "Cornish Red" sand	—	0·6	37·3	42·7	5·7		13·7	80·6

TABLE SHOWING GRADING OF SANDS.

Approx. I.M.M. Mesh.	G.						Sand grade (S.). / Silt grade (s.).
		Greater than 2·0 mm. diameter					Gravel grade (G.).
12–5	VCS	"	1·0	"	and less than 2·0 mm.		Very coarse sand
20–12	CS.	"	0·5	"	1·0 "		Coarse sand
50–20	MS.	"	0·25	"	0·5 "		Medium sand
120–50	FS.	"	0·1	"	0·25 "		Fine sand
180–120	cs.	"	0·05	"	0·1 "		Superfine sand or coarse silt
—	fs.	"	0·01	"	0·05 "		Fine silt
—	c.				0·01 "		Clay or mud grade (c.).

* "A Memoir on British Resources of Refractory Sands for Furnace and Foundry Purposes," page 15. Published at the Instruction of the Ministry of Munitions. Taylor and Francis, Red Lion-court, Fleet-street, London, 1918.

† *Op. cit.*, p. 20.

ON THE WOODY STRUCTURES OF FRACTURES OF TRANSVERSE TEST-PIECES TAKEN FROM CERTAIN SPECIAL STEELS.

By J. J. COHADE (Le Creusot).*

IN a paper read before the September meeting of the Iron and Steel Institute in 1918, Mr. Charpy showed the injurious effect of a high degree of deformation on the results of the mechanical tests obtained from test-pieces cut transversely from forged parts. The discussion which ensued gave rise to very interesting remarks by Drs. Stead, Rosenhain, and Hatfield, Sir Robert Hadfield, Mr. Cosmo Johns, and others on the causes of this inferiority in transverse tests.

The author wishes to point out, in this connection, that in special steels, and particularly in nickel steels, in which the phenomena in question are even more strongly marked than in ordinary steels, the carbon percentage plays a very important part.

Defective Transverse Tests.—It is found, in tensile tests, that the elastic limit and the breaking strain are practically the same or only slightly lower—given the same characteristics—in the longitudinal direction of the piece. On the other hand, the contractions and the elongations are lower. Impact test bars withstand a smaller number of blows; notched bars withstand, section for section, fewer kilogrammetres, and the bending test bars break at a lower angle. At the same time, the fracture surfaces are streaked with parallel lines resulting from the intersection of that surface with surfaces parallel with the axis given to the structure of the metal during forging. For this reason such fractures are described as "woody fractures." (See Fig. 1.)

Origin of these Streaks.—These streaks may result:—

1. Mostly from the presence of non-metallic inclusions.
2. Much less frequently from numerous tiny blowholes.
3. From the chemical composition of the metal.
4. From overworking.

We will leave aside the influence of working, which has been very minutely and very completely dealt with by Mr. Charpy in the paper to which reference has been made. If exception be made of the second cause enumerated above, the other three causes intervene simultaneously in all steels and make it difficult to separate the particular influence of each on the results.

(a) *Presence of Non-Metallic Inclusions.*—The author will not dwell on the formation of non-metallic inclusions in steels, which has been explained by many metallurgists, and, more especially and with much care, by Dr. McCance.† The influence of such inclusions on defective transverse results, and therefore on woody fractures, cannot be doubted. There is sometimes found, during the manufacture of gun steel carried out with every precaution and yielding very excellent results, an occasional cast of normal composition giving poor results and woody fractures. If these be examined under a magnifying-glass there will generally be seen more or less greenish inclusion stains, elongated in the direction of the streaks. In cases where a simple examination with a lens does not suffice, a microscopic examination of a small sample of the metal, after polishing and slightly etching, will reveal abnormal amounts of non-metallic inclusions. There will be seen on the surfaces of tensile test-pieces which have given these defective results, slight cracks or, at least, faint depressions. If the bar be broken carefully, by bending, at these points, inclusions will be found.

The formation of streaks in fractures, owing to the influence of inclusions, is easily explained. The original globules, more or less ovoid in form, become flattened and elongated parallel with the direction of the flow of the metal during forging. When the steel is subjected to a tensile stress perpendicular to this direction it cannot elongate at the points at which these inclusions are found, for, at these points, fracture has already taken place. What occurs is as though the bar had a series of internal parallel notches preventing the elongation of the neighbouring metal and fracture takes place suddenly, passing from one notch to the next and producing the typical stepped fracture which is described as "woody" and which characterises these steels.

(b) *Presence of Numerous Tiny Blowholes.*—Tiny blowholes which have not been welded-up during forging will similarly form planes of separation parallel with the direction of the working of the metal and play exactly the same part as inclusions.

(c) *Chemical Compositions of the Metal.* 1. *Molybdenum Steels.*—The author was much struck in 1894 with the influence which the chemical composition of the metal might exercise on the defective results of transverse tests with woody fractures.

A series of molybdenum steels were studied in the form of small ingots cast from crucibles.

The results having been very satisfactory it was decided to run some charges in a 10-ton basic open-hearth furnace in order to ascertain what difficulties their furnace manufacture might present and to cast ingots of sufficient size to investigate their different possible applications.

One of these casts (No. 930) had the following composition:—

	Per cent.
Carbon	0·360
Silicon	0·041
Sulphur	0·017
Phosphorus	0·016
Manganese	0·420
Molybdenum	0·470

* Paper read before the Iron and Steel Institute, September 19, 1919.

† Journal of the Iron and Steel Institute, 1918, No. I. page 239.

The metal was therefore very pure and was prepared with great care.

One of the ingots was made into a gun tube. All the tensile test-pieces cut transversely gave low contractions and elongations, and woody fractures. The first impulse was to attribute this lack of success solely to the presence of oxides, or other non-metallic inclusions, inevitable when working by basic open-hearth.

It was possible, however, that the molybdenum itself might intervene, and to clear up this question the laboratory experiments were resumed. Two small ingots of 10 kg. each were made in the crucible, one with molybdenum and the other without. Their composition was as follows:—

—	With Molybdenum.	Without Molybdenum.
	per cent.	per cent.
Carbon	0·300	0·450
Silicon	0·170	0·190
Sulphur	0·016	0·020
Phosphorus	0·029	0·026
Manganese	0·120	0·420
Molybdenum	0·530	nil

These small ingots, which were square in section (80 mm. by 80 mm.) were transformed, by forging, into

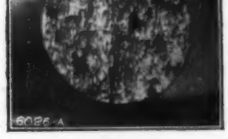
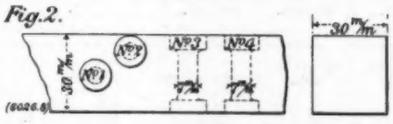
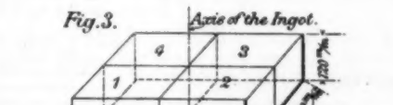


FIG. 1.





square bars 30 mm. by 30 mm., and annealed at 900 deg. and cooled in air.

After cropping 4 per cent. from the bottoms a piece 260 mm. long was cut longitudinally from each and two test-bars 13·8 mm. in diameter and 100 mm. long between punch marks were machined from them. They gave the following results:—

—	Elastic Limit per Sq Mm.	Tensile Strength per Sq. Mm.	Elongation per Cent.
	kg.	kg.	
With molybdenum	57·3	71·6	16·3
Without molybdenum ..	37·2	65·5	19·0

A length of 150 mm. was cut from the continuation of the bars which furnished the above test-pieces, quenched in water from 900 deg. C., and annealed at 600 deg. C. Small transverse bars were also taken, as shown in the sketch (Fig. 2). Nos. 1 and 3 were at right angles to each other and followed the axis of the bar; Nos. 2 and 4 were similarly at right angles to one another and cut in such a manner that their heads were tangential to the side surfaces. The results of the tensile tests are given in the table in the next column. The elongation being, owing to the dimensions of these bars, meaningless, have not been given.

It will be seen that the ordinary steel gave no streaks, whereas all the molybdenum steel bars presented them. They are barely appreciable in the bars cut from the edges, although they actually exist; they are much more marked in the bars cut along the axis. The dimensions of the ingots being very small and the test-pieces having been cut from the portion corresponding with one-third of the ingot, it was hardly probable that the difference between the results was due to segregation; it might rather be attributed either to the differences in crystallisation—needle-shaped along the edges, equiaxial in the centre portion—or simply to some slight porosity of the latter. It may be pointed out that microscopic examination of these small samples showed that the metal was practically free from inclusions.

It would therefore appear highly probable that molybdenum, even in small quantities, intervenes to accentuate the bad results of transverse tests.

Description of the Bars	Tensile Strength.	Appearance of the Fractures.
	kg. per sq. mm.	
Molybdenum steel—		
No. 1	96·6	Fine lines; low contraction.
No. 2	105·7	Lines hardly visible; fairly good contraction.
No. 3	94·0	Fine lines; low contraction.
No. 4	106·0	Lines hardly visible; fairly good contraction.
Steel without molybdenum—		
No. 1	90·5	No lines, good contraction.
No. 2	92·3	No lines, good contraction.
No. 3	89·3	No lines, good contraction.
No. 4	91·9	No lines, good contraction.

Tests of Treatments intended to improve the Results from Test-Bars cut transversely from Molybdenum Steels.—These tests can be grouped into three categories:—

(1) Modification of the structure of the ingot by more rapid cooling.

(2) Modification of the structure by forging at a higher temperature.

(3) Modification, after forging, by reheating and quenching.

First Group.—Two small molybdenum steel ingots, of the same dimensions and practically of the same composition as the foregoing, were cast, after melting in crucibles, one in the ordinary way and one into an ingot mould plunged into water. The transverse fracture of these two ingots, within 40 per cent. of the bottom, was very sound; that of the ingot cast into the water-cooled mould revealed bacillus-like crystallisation going right through to the centre, whereas in the other ingot this structure only occupied a superficial zone about 15 mm. thick. After forging the portions representing the 40 per cent. lower ends of the ingots a length of 150 mm. was cut from the bar and this piece was quenched and annealed and transverse test-bars cut from it as previously described. The fractures of the pieces along the edges showed very fine, barely perceptible lines; those of the central bars were better marked; in spite of the difference in the crystallisation the results were identical in both ingots, which shows that the difference in the results given by the test-pieces along the edge and those from the centre in the previous tests cannot be attributed to this cause, and was probably due to a slight degree of centre porosity produced during solidification.

Second Group.—An ingot from basic open-hearth cast No. 930, to which reference has previously been made, was cropped 40 per cent. from the top, after which a slice 120 mm. thick was taken and divided into four portions, as shown in Fig. 3. The treatments to which each part were submitted were as follows:—

Slab No. 1.—Water-quenched from 1050 deg. and then forged between 950 deg. and 800 deg.

Slab No. 2.—Water-quenched from 1050 deg. and then forged between 1100 deg. and 950 deg.

Slab No. 3.—Same treatment as No. 2 (above).

Slab No. 4.—Unquenched; forged between 1100 deg. and 950 deg.

The slabs, which were originally 170 mm. by 170 mm. by 120 mm. were reduced by forging to flats 200 mm. long and 35 mm. in section, their length being parallel with the 120 mm. side, that is to say with the axis of the ingot.

Results.—Tensile test bars were cut in the directions of the thickness and width of the flats and the results obtained gave rise to the following observations:—

(1) Quenching prior to forging effected no improvement.

(2) The fractures were "woody" whether forging was carried out between 1100 deg. and 950 deg. or between 950 deg. and 800 deg.; except that the streaks were less marked in regard to the bars from slabs forged between 1100 deg. and 950 deg.

(3) The differences were fairly marked according to the position from which the test-pieces were cut. Those corresponding with the edges of the ingot were better than those corresponding with parts in the neighbourhood of the centres.

Thus, with this ingot, of fairly large dimensions, the same peculiarities occur as in the small ingots of crucible steel cast in the laboratory.

Third Group.—The test-bars were cut transversely from a 75-mm. gun tube forged from an ingot of cast 930 which furnished the slabs described above. They were divided into two groups. Those of the first set were quenched in water from temperatures of 780 deg., 850 deg., 1000 deg., 1100 deg., and 1170 deg. respectively, as soon as the pyrometer showed that the required temperature had been reached. Those of the second group were treated the same way except that the temperature was maintained for one hour before the bars were quenched.

All the fractures showed lines; a slight improvement was, however, detected in the bars kept at between 1100 deg. and 1170 deg. for an hour before quenching.

To conclude, it would appear that forging at a high temperature, and also that quenching after keeping at a high temperature, will both improve the results, although this improvement is insufficient.

2. *Tests on various Special Steels.*—During the years

TEST RESULTS ON STEELS CONTAINING OVER 0·30 PER CENT. CARBON AND MORE THAN 2·5 PER CENT. OF NICKEL.

No. of Cast.	Composition. Carbon.	Composition. Nickel.	End Temperature of Forging.	Treatment of Bars.	Tensile Tests. A. Bottom. Working 1 : 4. Elastic Limit.	Tensile Strength.	Elongation per Cent.	$\frac{S-s1}{S}$	Fracture.	C. Bottom. Working 1 : 7. Elastic Limit.	Tensile Strength.	Elongation per Cent.	$\frac{S-s1}{S}$	Fracture.	D. Centre. Working 1 : 7. Elastic Limit.	Tensile Strength.	Elongation per Cent.	$\frac{S-s1}{S}$	Fracture.	B. Head. Working 1 : 7. Elastic Limit.	Tensile Strength.	Elongation per Cent.	$\frac{S-s1}{S}$	Fracture.
			deg.		kg.	kg.				kg.	kg.				kg.	kg.				kg.	kg.			
919	0·320	3·22	625–700		45·5	66·8	22·4	0·318	0	39·3	62·3	21·2	0·183	2	0·8	65·3	18·4	0·232	2	48·1	65·5	16·0	0·220	2
					43·6	66·1	24·0	0·416		40·5	64·7	21·2	0·237		40·5	64·7	18·4	0·213		48·0	65·4	16·8	0·296	
924	0·330	3·30	925	Heated to 850 deg., then cooled in air	43·7	66·3	25·6	0·456	0	40·2	64·5	24·0	0·362	1	40·6	63·6	16·0	0·235	2	43·8	65·2	16·0	0·196	3
					42·4	66·3	23·2	0·392		41·2	64·2	21·2	0·255		39·5	63·8	16·8	0·180		44·0	65·4	16·0	0·194	
1,004	0·451	3·25	900–925		48·9	76·7	21·6	0·300	1											52·0	76·0	16·8	0·245	2
					50·7	77·3	23·2	0·270												50·2	77·4	13·2	0·207	
1,005	0·434	3·22	625–700		47·8	67·8	20·8	0·298	1											49·4	69·5	12·8	0·192	3
					48·2	68·8	20·0	0·273												47·3	69·0	14·8	0·184	
919	0·320	3·22	625–700		60·7	75·5	19·2	0·275	3	61·8	78·0	14·8	0·240	2	59·3	76·8	19·2	0·263	3	59·2	75·3	22·0	0·406	1
					60·2	74·8	13·2	0·138		61·6	77·7	13·2	0·241		60·9	77·1	14·8	0·208		59·0	74·6	23·2	0·424	
				Tempered in oil at 875 deg., then tempered in water at 640 deg.	*58·4	74·5	16·0	0·247	3											*60·4	76·2	15·0	0·232	3
					*58·4	74·6	16·0	0·247												*60·4	76·2	13·6	0·232	
924	0·330	3·30	925		57·0	73·0	18·0	0·198	2	59·4	74·2	20·4	0·358	1	58·8	75·0	19·6	0·243	3	58·8	73·5	20·0	0·267	2
					57·5	72·5	20·0	0·292		58·2	73·1	13·6	0·257		59·4	74·3	13·6	0·213		58·4	73·4	19·6	0·283	
1,004	0·451	3·25	900–925		70·0	86·2	18·8	0·358	1											70·5	81·5	8·0	0·071	5
					72·0	88·0	18·0	0·320												67·8	76·7	7·2	0·063	
1,005	0·434	3·22	625–700		54·7	74·9	13·2	0·193	3											71·7	88·0	12·0	0·126	4
					53·4	74·7	16·4	0·245												72·2	88·3	15·2	0·243	

* Tests made on a second bar.

75 MM. GUN TUBE—CAST NO. 4928, JUNE 3, 1898. ACID OPEN-HEARTH NO. 6.

Description of Tests.	Treatment.	Tensile Tests on Bars 50 mm. Long and 13·6 mm. Diameter Cut Transversely in the Middle Thickness. Elastic Limit.	Tensile Strength.	Elongation per Cent.	Reduction of Area, $\frac{S-S'}{S}$.	Fracture.
		kg. per sq. mm.	kg. per sq. mm.			
Tests before quenching	Annealed after forging at 900 deg.					
	Breech end	42·7	61·0	24·5	0·460	B*
	Muzzle end	43·0	61·3	24·0	0·453	B
Tests after quenching	Quenched in water at 900 deg. C. and again quenched at 620 deg.					
	Breech end	61·0	82·5	19·0	0·389	B
	Muzzle end	57·7	79·5	23·5	0·468	B

* The letter B stands for fractures known in England as "half-cup."

1894 to 1898 a large number of special steels had to be examined transversely in the laboratory, and the conclusion was arrived at that good results could be obtained—the fractures being free from streaks—when the carbon percentage did not exceed 0·25, even with fairly high percentages of the special elements, reaching, for example, in the case of nickel, as much as 7 per cent.

As a result of these conclusions a certain number of casts were made from an open-hearth furnace, some on a basic lining and others on an acid lining. Those made by the basic process showed few or no lines, but side by side with test-bars giving good fractures were others showing small whitish stains, oval and in all probability identical with the defect which has recently been described in various English and American Reviews under the name of flakes, which prevented such steels being accepted as suitable metal for guns.

The casts from the acid open-hearth made with all the precautions observed in gun manufacture, much slower working of the charge, charging in several relays, &c., gave, on the contrary, excellent results. The table above gives those obtained on a 75-mm. gun tube forged from an ingot of the first cast made under these conditions.

The composition of this cast was: carbon, 0·240 per cent. silicon, 0·216 per cent.; sulphur, 0·022 per cent.; phosphorus, 0·031 per cent.; manganese, 0·430 per cent.; and nickel, 5·550 per cent. The average working was 1 : 3·4.

These acid furnace charges show that the upper limit of 0·25 per cent. fixed for the carbon may be raised to 0·30 and, even with 5 to 6 per cent. of nickel, yield excellent fractures.

A fact that supports the foregoing contention on the subject of the upper limit of the carbon is the following:

During the war, tests were made of six rings from the breech end obtained from foreign material for 155-mm. guns. Five of these pieces had a composition closely agreeing with the above: carbon, 0·25 per cent.; silicon, 0·25 per cent.; manganese, 0·50 per cent.; nickel, 3·60 per cent.; and chromium, 0·80 per cent. They yielded excellent fractures.

The composition of the sixth was: carbon, 0·340 per cent.; silicon, 0·320 per cent.; manganese, 0·700 per cent.; nickel, 2·760 per cent.; and chromium, 0·115 per cent. These bars gave the same elastic limits and tensile strengths as the previous ones, but the elongations and reductions of area were much smaller and the fractures were woody.

Fig. 4.

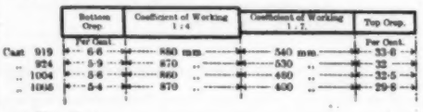
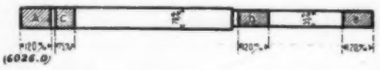


Fig. 5.



3. *Transverse Tests on Nickel Steels.*—The upper carbon limit of about 0·30 need not be kept to as long as the percentage of nickel does not exceed 2·5 per cent. Thus some hundreds of gun steel casts have been made at Creusot by the acid process with carbon percentages of 0·35 to 0·50 and with 1·8 to 2·4 per cent. of nickel, with excellent results, in a transverse direction. With more than 2·5 per cent. of nickel, however, it is necessary to diminish the carbon in order to avoid woody fractures. This fact appears to the author a strong argument in favour of the hypothesis put forward, namely, that defective transverse results and correspondingly woody fractures may arise, not only owing to the presence of inclusions or blowholes or to overworking, but also owing to the chemical composition of the metal.

It can indeed hardly be doubted that if it be possible to make two casts by the acid open-hearth process, and with every imaginable precaution, one with, for example, 0·25 per cent. of carbon and 4 per cent. of nickel, and the other with 0·40 per cent. of carbon and 4 per cent. of nickel, it is more difficult to avoid oxidisation and the presence of inclusions in the former than in the latter, yet, however, the former will give good transverse fractures and the second will give streaky fractures even when the treatment has been adjusted so as to give, in both instances, the same tensile strength on testing.

The latter condition is necessary to afford comparisons, as it may often be found that a steel which in the annealed state does not show a streaky fracture, will show streaks once quenching has increased its tenacity. It appears probable to the author that the improvement due to a low percentage of carbon is the result of less segregation around the dendritic crystals formed during solidification, owing to the greater speed with which this takes place.

Experiments made with the object of improving the transverse test results in steels containing over 0·30 per cent. of carbon and more than 2·5 per cent. of nickel.—The programme of these experiments was drawn up in order to investigate the influence of—

1. Percentage of carbon above 0·30.
2. The end temperature of forging.
3. The coefficient of working, &c.
4. The position of the test samples with regard to the ingot.

With these objects, four ingots of 130 mm. by 130 mm. section, and weighing about 75 kg. each, were cast from the crucible furnaces of the steelworks, the lower ends of the ingots being smaller than the tops. Their composition is shown in the following table:—

No. of Cast.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Nickel.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
919	0·320	0·272	0·026	0·039	0·480	3·22
924	0·330	0·280	0·028	0·037	0·440	3·30
1,004	0·451	0·257	0·030	0·037	0·500	3·25
1,005	0·434	0·224	0·028	0·041	0·490	3·22

Forging.—These ingots were forged under a 2,000-kg. hammer. The ingots from casts 919 and 1005 underwent three reheatings at between 1075 deg. and 625 deg. C. The other two were forged in five heats at temperatures between 1050 deg. and 600 deg. The sketch (Fig. 4) shows the shape and dimensions of the pieces after forging as well as the percentage crops top and bottom.

After forging the four rounds were annealed at 950 deg. and air cooled. From each end of each round, a piece 120 mm. long was cut. These pieces were marked A and B (see Fig. 5). The pieces taken from the bottom end were drilled along their axes with a hole 20 mm. in diameter, and those from the top end with a hole 10 mm. in diameter, in order to secure approximately the same thickness of metal and to be able to obtain smaller bars.

In casts 919 and 924 only, there were then cut, about midway along the length but on the portion reduced to 55 mm., a sample D, 120 mm. in length, and from the bottom end a sample C, 75 mm. long, which was reforged to 55 mm. The forging down was carried out at the same temperature as the first forging, that is to say between 950 deg. and 625 deg. for the round from cast 919 and between 1000 deg. and 900 deg. for the round from cast 924.

The lengths obtained were, like the previous ones, bored with 10-mm. holes.

By acting thus it was possible to determine:

(1) The influence of the carbon by comparing the results of the tests of the lengths:—

A. Casts 919–1005
B. ,, ,, ,,
A. ,, 924–1004
B. ,, ,, ,,

These lengths have, in each series, undergone the same amount of working and the same method of forging.

They likewise occupy the same relative positions in the ingot. The percentage of carbon is the sole difference between them.

(2) The influence of the end temperature of forging, by comparing the results of the tests of the lengths :—

A. Casts 919–924
B. „ „ „
C. „ „ „
D. „ „ „
A. „ 1004–1005
B. „ „ „

These lengths had, so far as each series was concerned, undergone the same amount of work ; they occupy the same relative positions in the ingot and have practically the same percentages of carbon. They differ solely in respect to the end temperatures of forging.

(3) The influence of the amount of working, by comparing the results of the tests of the lengths :—

A—C. Cast 919
A—C „ 924

These lengths have the same carbon percentages and have undergone, in pairs, the same method of forging and occupy the same relative positions in the ingots. The amount of work they have undergone is their sole difference.

(4) The influence of the relative positions of the samples in the ingots, by comparing the results of the tests of lengths :

C—D—B. Cast 919
C—D—B. „ 924

These lengths have the same carbon percentages ; have undergone—as regards each cast—the same method of forging, and have undergone the same amount of work. Their position, in respect to the ingots, are their sole differences.

All the lengths forged to 55 mm. were machined down to 50 mm. and the 70-mm. lengths were machined down to 65 mm., after which they were again annealed at 850 deg. and air-cooled. From each of them a rod 12 mm. thick was then cut, for testing before quenching. Each rod furnished two tensile test bars 6·9 mm. in diameter and 25 mm. in length between punch-marks (homologous with those 13·8 mm. in diameter and 50 mm. long between punch-marks). These bars were cut as shown in Figs. 6 and 7.

The rods were subsequently quenched in oil from 875 deg., and in water from 640 deg.

A fresh rod 12 mm. thick was taken from each sample and sliced as before.

The Table on page 422 sums up the results of these tests. In the columns headed "fracture" the figures 0, 1, 2, 3, 4 and 5 have been used to signify the relative proportion of streaks. Those marked 0 show none ; those marked 5 reveal the most.

By instituting the comparisons as already described, so that in each instance there is but one variable, it is found :

1. As regards the influence of the carbon : in eight examples five are favourable to the less highly carburised casts ; one gives identical results in both cases, and two favour the more highly carburised casts. It may therefore be concluded, as before, that from the point of view of the test results it is advantageous to reduce the carbon percentage.

2. As regards the influence of the end temperature of forging, it is found that out of twelve instances six favour high finishing temperatures, three are identical both as to high or low finishing temperatures, and three favour low temperatures. From this the conclusion can be drawn that it is preferable to finish the forging at as high a temperature as possible.

3. In regard to the amount of working the results are indecisive. There are two instances where the 1 : 4 working is advantageous and two instances where it is the reverse. The author believes this to arise from the small number of tests and, more especially, from the small dimensions of the ingots.

4. From an examination of the results from the bottom, the centre, and the head of the ingots it results that the bottom portion is distinctly better. The difference between the other portions is inappreciable.

5. It should likewise be noted that, generally speaking, the fractures are more woody after quenching than in the annealed bars. Thus, the tests, before quenching, on test-pieces from the bottoms of ingots worked 1 : 4 show no streaks, although they show them after quenching and annealing.

To sum up : What this investigation brings out is that forging finished at a high temperature improves the results of transverse tests, although it does not do so sufficiently. Hence, if very good results be sought it is preferable to diminish the percentage of carbon to below 0·30 per cent., if the percentage of nickel has to be increased in order to obtain the necessary tensile strength after quenching.

Conclusions.

In addition to the part played by non-metallic inclusions, blowholes, and amount of working, in giving bad results in transverse tests of forged parts, it is necessary to take into consideration the chemical composition of the steels and particularly of the percentage of carbon.

When this is below 0·30 per cent., and better still, below 0·25 per cent., good results are obtained if the metal has been properly made, even when added a sufficiently high percentage of special metals to secure very high tensile strength after quenching and annealing. This rule applies up to steels which have undergone a 1 : 8 working, but the author has no experience of higher coefficients of working.

It is not necessary to lower the carbon in nickel steels so long as the percentage of nickel is below 2·5. Very good results are indeed obtained with percentages of carbon reaching 0·5, as has been shown by numerous tests on steel manufactured for ordnance.

It would appear that the transverse tests are improved if the forging of the ingot be wholly carried out at a high temperature, but this improvement is insufficient when

Fig.6.

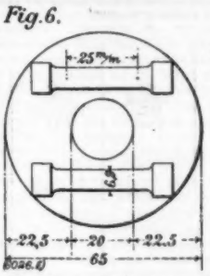
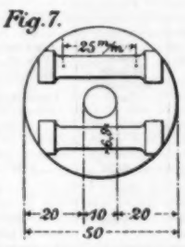


Fig.7.



the maximum results are required in transverse strength, as, for example, in the case of steel for guns.

The different tests described in this paper having been carried out at different times and over a prolonged period, lack the co-ordination they might have possessed had they been carried out as a whole. For this the author offers his apologies.

He desires, in conclusion, to express his thanks to Mr. Schneider for having authorised the publication of these results.

New Board of Trade Administrative Council.—The President of the Board of Trade has established an internal Administrative Council, which includes the Parliamentary and Permanent Secretaries and the heads of the chief administrative Departments. The Council will meet regularly and frequently to deal with current business involving questions of policy. Sir H. Llewellyn Smith, G.C.B., Permanent Secretary of the Board of Trade, has been appointed to the post of Economic Adviser with reference to the larger national and Imperial economic questions, especially for the present those arising out of the Peace settlement and the transition to normal conditions. He will retain close connection with the Board of Trade in the capacity of vice-president of the Administrative Council, over which he will preside in the absence of the President of the Board of Trade. The President of the Board of Trade has appointed Mr. S. J. Chapman, C.B., C.B.E. (Senior Assistant Secretary, General Economic Department), and Mr. H. A. Payne, C.B. (Comptroller of the Companies Department), to be Joint Permanent Secretaries of the Board of Trade. The Administrative Council referred to above is quite distinct from and in no way supersedes the Board of Trade Advisory Council, on which manufacturers, traders and Labour are represented.

Diesel Engines for the United States.—The United States Shipping Board, says the *American Marine Engineer*, has taken over the American rights to manufacture one of the standard European Diesel engines, and will build the engines on a vast scale, according to advices received from Washington. A contract for the construction of the engines has been let in Pennsylvania, and in less than three months one completed Diesel engine will be delivered each day. The production, it is said, will be increased to two engines each day before the end of the year. The decision of the Shipping Board to undertake motor ship construction was made more than a year ago and was influenced by the official announcement of the East Asiatic Steamship Company, of Copenhagen, that the concern had decided to dispose of all its steamships and build and utilise only the motor ship in the future. Shortly afterward several of the largest Scandinavian shipping concerns made a similar announcement, which was followed by another from England to the effect that all of the shipbuilding yards of the United Kingdom were fully booked with orders for motor ships for at least three years. The bulk of these were for the Scandinavian concerns. Several engineering experts of the Shipping Board went to Europe and made an exhaustive investigation of the internal combustion engine. It was decided that a certain standard Diesel, manufactured in Denmark, would best meet the needs of the American merchant marine, and a single engine was purchased and delivered at New York, together with the patent right for American manufacture. The engine was taken down and re-assembled dozens of times. Patterns and drawings were perfected and special machines for the finishing of each casting are being made. Officials of the Shipping Board believe that when the manufacturing programme is fully under way it will be possible to produce the engines as quickly as they are needed for installation in the hulls of the new ships. Shipping Board officials say that America is compelled to adopt the motor ship at this time to be prepared to meet competition under normal conditions. The chief reasons given for discarding the steamship in favour of the motor ship, especially for the transportation of overseas freights, are :—The saving of two-thirds of the oil used as fuel ; a saving of more than 25 per cent. of wages, due to the cutting down of the engine-room force and the entire elimination of the fire-room gang ; the corresponding decrease in the cost of operation, it being found possible to carry an average of 15 per cent. more freight ; the resulting conservation of the world's supply of petroleum ; the increase of a vessel's steaming radius from a few thousand miles to not less than 30,000 miles.

FUEL ECONOMY IN THE IRON AND STEEL MANUFACTURE.

*A Report on "Fuel Economy and Consumptions in the Manufacture of Iron and Steel."**

Presented on behalf of the British Association Fuel Economy Committee by Professor William A. Bone, D.Sc., F.R.S. (Chairman), Sir Robert Hadfield, Bart., F.R.S., and Mr. Alfred Hutchinson, M.A.

(*Concluded from page* 396.)

B. Open Hearth Steel Works Fuel Consumption.

We have found it more difficult to analyse and compare the returns of fuel consumptions from steel works than in the case of those from blast-furnace plants, because of the much greater differences in working conditions. These differences were chiefly in (1) the types and sizes of the open-hearth furnaces employed, (2) the character and proportions of metal (pig and scrap) in the charge per ton of ingots produced, (3) the proportions of molten and cold metal in the charge, (4) the type of sections finally rolled. We are therefore fully aware of the provisional nature of such classification and comparison of the returns as we have attempted, and only put them forward as being the best that can be given in the circumstances. It would be unfair to institute any very close comparison between one return and another, even where the operating conditions appear to have been comparable. The chief value of the data comprised in the returns lies in the fact that they will perhaps enable the fuel technologist to form a fairly good idea of the possible margins of economy, and the direction in which to look for them, in British steel works practice. For the sake of convenience, we propose to use the following descriptive terms :—

"*Molten Pig Processes.*"—Where 85 per cent. (no more) of the total metal charged was made up of molten pig-iron from the blast furnace.

"*Mixed Processes.*"—Where the proportion of molten pig-iron in the charge varied between 40 per cent. and 70 per cent., the remainder of the material (pig-iron and scrap) being charged in cold.

"*Cold Processes.*"—Where no molten metal at all was charged.

First Group.—Returns from Steel Works Employing "Molten Pig Processes" in Conjunction with Blast Furnaces.

Returns were forthcoming from four firms who are working molten pig-iron processes in conjunction with blast furnace plants, where alone it is possible to achieve an ideal fuel economy in steel-making. In analysing them, we have attempted to deduce from the data placed at our disposal an estimate not only (*a*) of the actual coal (*i.e.*, excluding the coal equivalents of any coke-oven or blast-furnace gas used) consumed in the various successive operations involved in the conversion of the molten pig-iron into finished steel sections, but also (*b*) of the total coal that would have been used in producing a ton of finished steel sections from the original iron ore, on the supposition that the blast-furnace coke had been made by carbonising a suitable coal in by-product recovery ovens. This last-named figure is the more interesting and important of the two, because it really brings into the account any use made of the blast-furnace and coke-oven gases, either on, or in connection with, the blast furnaces, steel works and rolling mills, and shows at a glance how far the plants in question were from achieving the "ideal" fuel economy referred to in a previous section of this report.

The returns from these four firms have been analysed and tabulated as follows. See Table IV.

It would thus appear that in the Cleveland district the total coal consumption in the steel works varied, on representative well-equipped plants, between 10 cwt. and 12·5 cwt. per ton of finished sections, over and above that used on, or in connection with, the blast furnaces. The total coal consumption from ore to finished sections was probably in no case lower than 40 cwt. and might amount to 45 cwt. (and in some cases even more) per ton of steel output. In the case of the two Lincolnshire plants, the total consumption from ore to finished sections came out at about 50 cwt. to 55 cwt. per ton respectively.

Assuming these to be fairly representative figures, it is clear that further great economies remain to be achieved before we shall have arrived at the conditions which should be aimed at, and which we regard as possible of achievement in the case of plants situated as these are. The possible further margin of economy in such Cleveland plants would appear to be in most cases

Firm No.	From	Percentage Composition of Waste Gases				Average Temperature.
		CO_2.	CO.	O_2.	N_2.	
						deg. C.
VI.	Open-hearth furnaces ..	9·2–14·3	nil	4·5–8·0	80·8	560
	Soaking pits	7·5	nil	10·6	82·9	350–600
	Boilers—					
	Gas-fired	17·9	nil	4·9	77·2	600
	Coal-fired	11·6	nil	7·4	81·0	237
IX.	Open-hearth furnaces ..	10·15	nil	6·0	83·85	400
	Boilers ..	12·95	nil	5·15	81·90	250

* Report submitted at the Sheffield meeting of the Iron and Steel Institute, on Thursday, September 18.

TABLE IV.—COAL CONSUMPTIONS IN STEELWORKS USING "MOLTEN PIG PROCESSES" IN CONJUNCTION WITH BLAST-FURNACES.

Firm No.	Metal Charged per Ton of Ingots made.			Types and Sizes of Open-Hearth Furnaces.	Actual Coal Consumption at Steelworks per Ton of Finished Sections.					Coal Consumptions at Blast Furnaces and Coke Ovens per Ton Finished Sections.			Grand Total. Cwt. of Coal Consumed from Ore to Finished Steel Sections.
	Molten Pig-Iron. Cwt.	Cold Pig-Iron. Cwt.	Cold Scrap. Cwt.		(a) Open-Hearth Furnaces. Cwt.	(b) Soaking Pits or Reheating Furnaces. Cwt.	(c) Rolling Mill. Cwt.	(d) Other Purposes. Cwt.	Total. Cwt.	At Coke Ovens. Cwt.	For Calcining and other Purposes. Cwt.	Total. Cwt.	
VI.	16·16	1·63	0·13	Basic. 7 × 55 tons 2 × 65 tons	6·36	1·46	2·44	1·79	12·05	28·70	2·65	31·35	43·40
VII.	17·5	nil	1·73	Basic. 1 × 250 tons Talbot 2 × 60 tons Wellman	6·09	nil B.F. and C.O. gases used		4·76	10·85	27·77	3·03	30·80	41·65
VIII.	17·5	nil	2·00	Basic. Talbots. 100 to 175 tons	6·00	3·50	3·50	2·00	15·00	40·00	nil	40·00	55·00
IX.	17·0	nil	3·25	Basic. 4 × 45 tons producing high-grade alloy steels	7·00	3·00	nil B.F. gas used	1·65	11·65	38·25	nil	3 ·25	40·90

TABLE V.—COAL CONSUMPTIONS IN STEELWORKS USING "MIXED PROCESSES" IN CONJUNCTION WITH BLAST-FURNACES.

Firm No.	Metal Charged per Ton of Ingots			Types and Sizes of Open-Hearth Furnaces.	Actual Coal Consumptions at Steel Works per Ton of Finished Sections.					Coal Required at Coke Ovens and Blast Furnaces to Produce the Pig-Iron used. Cwt.	Grand Total of Coal Consumed. Cwt.
	Molten Pig. Cwt.	Cold Pig. Cwt.	Cold Scrap. Cwt.		(a) Open-Hearth Furnaces and Mixed. Cwt.	(b) Soaking Pits and Reheating Furnaces. Cwt.	(c) Rolling Mills. Cwt.	(d) Other Purposes.	Total Cwt.		
XII.	8 to 10	2·0	10 to 8	Basic. 6 × 45 tons 2 × 60 tons	6·25	3·05	1·5 partly driven by gas	nil	10·80	21·00	31·00
XIV.	14 to 15	nil	6·0 to 6·5	Basic. 2 × 25 tons 1 × 40 tons 1 × 50 tons 2 × 60 tons	8·75	5·1	5·50	nil	19·35	25·70	45·05
XVI.	12·4	0·8	6·7	Basic. ?	8·00	2·75	2·50	0·60	13·85	22·40	36·2

TABLE VI.

Firm No.	XV.	XXII.	XXIII.	
Metal charged per ton of ingots— Cold pig, cwt.	11·5	12·0	9·4 to 11·0	
Cold scrap, cwt.	12·5	9·0	11·0	
Type and sizes of open-hearth furnaces used	Basic. 14 tons	Acid. 2 × 22 tons 2 × 30 tons	Acid. 3 × 40 tons 1 × 50 tons	Basic. 5 × 50 tons
Actual coal consumption at steel works. Cwt. per ton ingots produced—				
(a) Open-hearth furnace and mixers	Cwt. 9·75	Cwt. 12·00	Cwt. 7·00	Cwt. 9·00
(b) Reheating furnaces, &c.	2·00	4·50	8·25	8·25
(c) Rolling mill	3·75	4·00	3·75	3·75
(d) Other purposes	3·00	1·25	1·25	2·00
Total cwt.	18·50	21·75	20·25	23·00

between 5 cwt. and 10 cwt. of coal per ton of finished steel sections; in the case of the Lincolnshire work, it would be decidedly greater. Firms Nos. VI and IX furnished the following details with regard to the temperatures and compositions of the waste gases from their open-hearth furnaces, soaking pits and boilers:—

SECOND GROUP.—RETURNS FROM STEELWORKS USING "MIXED PROCESSES."

Three other firms, all with steelworks connected with their blast-furnace plants, made returns which could be analysed in a similar way to those of the previous group. Seeing, however, that they were employing "mixed processes," it seemed advisable to deal with these as a separate group.

Any increase in the proportion of cold scrap in the charge might be expected to influence the fuel consumption in the open-hearth furnace in each of two opposite ways, namely, (a) increasing it, on account of the additional amount of heat required to melt the charge, but (b) decreasing it because of its dilution of the impurities to be removed. It would not, however, be likely to affect materially the consumptions of fuel in the soaking pits, re-heating furnaces, rolling-mills, &c. The returns now under consideration do not, however, show any marked differences from those of the previous group, so far as the open-hearth furnaces are concerned. Where, however, the total expenditure of fuel in the combined blast-furnace and steel plants per ton of finished sections is being considered, it is obvious that any large decrease in the proportion of pig-iron added to the charge in the steelworks must correspondingly reduce the amount of coal consumed at the coke-ovens, so that the grand total might actually work out less than for plants using "molten pig processes."

The returns in question are analysed in Table V. The amount of coal allowed for the manufacture of the proportion of pig-iron charged into the steel furnace has been calculated for each firm's own returns of blast-furnace coke consumptions, on the supposition that a 70 per cent. yield of coke was obtained at the by-product ovens.

Composition and Temperature of Waste Gases.

Firm No.	Gases from	Percentage Composition. CO_2.	CO.	O_2.	N_2.	Temperature.
XII.	Open-hearth furnaces	9·5	nil	8·8	81·7	deg. C. 480–870
	Coal-fired boilers	12·0	—	7·25	80·75	300–350
XIV.	Open-hearth furnaces	8·0	nil	9·5	82·5	525
	Soaking pits	4·0	nil	15·0	81·0	480
	Reheating furnaces	5·6	nil	13·0	81·4	320
	Boilers	5·9	nil	10·8	83·3	350
XVI.	Open-hearth furnaces	12·30	nil	8·65	80·05	620
	Reheating furnaces	13·60	—	—	—	200
	Boilers	12·0	—	—	—	210
		10·2	—	—	—	260

THIRD GROUP.—STEELWORKS USING "COLD PROCESSES."

Three firms using "cold processes" made returns which have been analysed as follows:—

The following particulars concerning the compositions and temperatures of the waste gases from the plants in question were supplied:—

Firm No.	Waste Gases from	Percentage Composition. CO_2.	CO.	O_2.	N_2.	Temperature.
XV.	Open-hearth furnaces	9·8	—	8·8	81·4	deg. C. 655
	Reheating furnaces	13·4	—	4·2	82·4	590
XXII.	Reheating furnaces	12·0	nil	4·2	83·8	565–785
	Boilers	6·8	nil	11·0	82·2	385
XXIII.	Open-hearth furnaces	CO_2 = 6·00 to 11·60				475–500*
	Reheating furnaces	CO_2 = 6·00 to 10·00				273
	Boilers and economisers	CO_2 = 8·40 to 10·40				260

* After passing through water-tube boilers.

SUMMARY OF RESULTS.

(1) As might be expected, the coal consumptions at the open-hearth furnaces proved to be least with the "molten pig" and greatest with the "cold" processes. Thus we find:

—	Cwt. per Ton of Ingots.	Average. Cwt.
(a) Molten pig-iron processes	6·00 to 7·00	6·35
(b) Mixed processes	6·25 to 8·75	7·65
(c) Cold processes	7·00 to 12·00	9·45

(2) It would appear that, averaging the returns for each type of process, the total amount of coal consumed between casting the steel from the open-hearth furnaces into ingots and finishing off the sections at the rolling-mills is, as a general rule, about equal to that consumed at the furnaces. Thus in the "molten pig process" returns, the total steelworks coal consumption averaged 1·9 times, in the "mixed process" returns 1·95, and in the "cold process" returns 2·2 times, that consumed at the open-hearth furnaces in each case.

(3) Almost all the returns relating to the compositions

and temperatures of the waste gases from steel furnaces, soaking pits, boilers, &c., reveal a considerable loss of heat, a large proportion of which would be recoverable in waste heat boilers. In many cases, also, far too great an excess of air was being used in the furnaces. Undoubtedly much fuel could be saved if more attention were paid to the proper proportions of the gas and air in the furnaces and to the recovery of the waste heat from the chimney gases.

C. Bessemer Practice.

Two of the firms making returns employed (*inter alia*) the Bessemer process. The data submitted from one of them did not suffice to enable us to deduce the fuel consumption in connection with the conversion process, apart from the subsequent finishing-off of the ingots. From the other firm's (No. XXIII.) returns the following information has been extracted :—

	—	Fuel per Ton of Steel Produced.		
		cwt.	qrs.	lb.
XXIII.	(*a*) Coal for steam-raising for blowing engine	2	2	22
	(*b*) Coke at cupolas	1	3	11
	(*c*) Coal for heating up ladles, &c.			10
	(*d*) All other purposes			23
	Total	4	3	10
	Or allowing for the coal equivalent ($\frac{100}{175}$) of coke	5	2	14

D. Coke Consumption in Crucible Steel Smelting.

Although the prime object of the Committee's inquiry was to obtain data concerning the consumption of fuel in the manufacture of structural steel, two Sheffield firms (Nos. XXIV. and XXV.) very kindly supplied certain information respecting the coke used in melting steel in their crucible furnaces. One of them reported a coke consumption of 2 tons 15 cwt., and the other of 3 tons 7¼ cwt. for the melting operation only (*i.e.*, not including annealing of the pots).

Both firms reported adversely regarding the substitution of by-product for beehive coke in their crucible furnaces. One said : "By-product coke is not so hard nor clean as beehive coke. The former gives an excess of slag in the bars and pots which prevents the necessary high heats being obtained." The other was even more decisive in their condemnation of by-product coke, saying : "By-product coke for crucible steel melting is altogether useless and could not be considered for one moment for the melting of modern steel such as high-speed steel and various other special steels. This coke has not sufficient heating power, owing, we presume, to so much having been taken out of it in obtaining the by-products."

These two opinions are reproduced, without endorsement or otherwise, because inquiry has shown that they are widely held in Sheffield. Whether or not (and if so, then to what extent) such allegations as the above about the inferiority of by-product coke for crucible steel melting are well founded ought, we consider, to be made the subject of a thorough and independent scientific inquiry in the interests of national economy. It can, however, be definitely said that there is no ground for the assumption that by-product coke has not sufficient heating power "owing to so much having been taken out of it in obtaining the by-products." Such differences as there may be between the suitability of beehive and by-product cokes for the purpose in question must (if they exist at all) be due to quite other causes which should be capable of discovery and precise definition. Moreover, if a real comparison is to be made between the suitabilities of the two kinds of coke in question, it ought to be in respect of consignments made from the same coal and not (as is often the case) as between cokes made from different coals. There seems no real ground for supposing that were the same coal carbonised (*a*) in "beehive" and (*b*) in modern "by-product" ovens respectively, the coke from the former would be either harder or cleaner than the other. The matter is one demanding much further investigation before any final conclusion can be reached.

In reply to the questions whether there is any practical objection to the use of gas instead of coke for melting purposes in the manufacture of crucible steel, one of the firms stated that they were able to control the heat more and get a better product with coke than with gas. The other firm said they had no experience of gas-melting, and therefore could not answer the question, adding, however, that exhaustive experiments made in Sheffield some years ago had resulted "in a draw" between gas and coke. It is to be hoped that if any records of such experiments exist some further information concerning them may be forthcoming during the discussion upon this report, because the subject is one of considerable importance and ought to be thoroughly explored.

Section IV.—Concluding Remarks.

(1) In concluding our task of analysing and presenting the mass of valuable data and information which was communicated by the 25 firms in question to the committee, we desire to say that we are fully aware how difficult it is to avoid the introduction of errors into the comparative statements and tables included in this report. There must necessarily have been some imperfections, both in the collecting of the data and the mode of analysing them, and the resulting records and comparisons have no doubt suffered to some extent. But we believe that no such complete nor comprehensive data have until now been collected and made available for public discussion, and that, notwithstanding the possibility of minor errors, certain broad general conclusions can be legitimately drawn from them.

(2) The results, as a whole, prove beyond all question that much yet remains to be done before British iron and steel works will have attained to anything like the practical ideal of fuel economy which at least three leading iron and steel makers have declared to be even now attainable. None of the returns show that, even where coke-ovens, blast-furnaces, steelworks, and rolling-mills are concentrated on one site and under one management, the manufacture of the steel and its subsequent rolling into finished sections have as yet been accomplished with no other expenditure of coal than that which must be charged into the coke-ovens to make the coke required for the blast-furnace. In his Memorandum to the Coal Conservation Committee in October, 1917, Mr. Benjamin Talbot estimated that a ton of finished steel sections could then be produced with no greater expenditure of fuel than 35 cwt. of coal at the coke-ovens. According to our analysis of the returns of the four firms using "the molten pig process," none of them are using less than 40 cwt. of coal per ton of finished steel sections, and two were using about 50 cwt. to 55 cwt.

(3) There are so many directions in which further large economies may be effected, even when the necessary concentration and co-ordination of plant units have been secured, that we cannot hope to do more than indicate a few of the more obvious of them. The surplus blast-furnace and coke-oven gases can undoubtedly be much better and more fully utilised than they are to-day on most plants. The data published in this report concerning the temperatures and compositions of waste gases from boilers, stoves, furnaces, and soaking-pits, show that the science of combustion is, as a rule, either imperfectly understood or very badly applied by those in charge of the plants. A great deal of heat can, and ought to be, recovered from such waste gases.

(4) Speaking of this aspect of the subject, Mr. Talbot, in the memorandum referred to, stated : "A point in fuel economy in connection with steelworks to which a considerable amount of attention is now being directed is the utilisation of waste heat in open-hearth furnaces flues by means of waste heat boilers . . . it is stated that a saving equivalent to 150 lb. to 200 lb. of coal per ton of steel ingots has been obtained from this waste heat."

(5) Again, in a paper read by Mr. C. J. Bacon before the American Iron and Steel Institute, in 1915, it was stated that : "Existing boilers on large open-hearth furnaces are showing a saving which, when expressed in terms of fuel required in coal-fired boilers, is equivalent to at least 250 lb. of coal (11,000 British Thermal units per lb.) per ton of ingots." Again, in a paper read in July last by Mr. C. J. Goodwin before the Annual Congress of the Society of Chemical Industry in London, it was estimated that in regenerative open-hearth furnaces, where the products of combustion, containing 5·0 per cent. of oxygen, pass up the chimney at an average temperature of 500 deg. C., as much as 33 per cent. of the net calorific value of the fuel is thus being lost.

(6) Such satisfactory progress is now being made with the electrostatic cleaning of blast-furnace gases, that the day may be confidently anticipated when all the gas (whether required for stoves or engines) will be so cleaned. This will undoubtedly increase the thermal efficiency of the hot-blast stoves, and make a larger surplus of gas available for the steel works.

(7) Speaking of the utilisation of the surplus gas for power purposes, it seems a barbarous practice to burn uncleaned blast-furnace gas in Lancashire boilers, whose efficiency probably does not exceed 55 per cent., when (if cleaned) its potential energy can be transferred into electric power *via* the gas-engine and dynamo. The day is fast approaching when, in steel works adjacent to blast-furnaces, all stationary machines (including blowing engines, cranes, and rolling-mills) will be electrically driven by current generated from the explosion of blast-furnace gas in internal combustion engines. Even now, steam-driven reciprocating blowing engines should be superseded by electrically driven turbo-blowers.

(8) When such reforms have been carried out in connection with the blast-furnace plants, we may look for the abolition of the "gas-producer" in the adjacent steel works, a step much to be desired. The blast-furnace is the place where all the coal on an iron or steel plant should be gasified after it has been carbonised in the coke-ovens.

(9) The problem of recovery and utilising the heat carried away in the molten slag from the blast-furnace is one which ought to be solved in the near future.

(10) We would again emphasise the view that the problem of fuel economy, as it presents itself to-day, is one rather of scientific organisation and co-ordination than of the discovery of new principles. In all the larger works there ought to be an organised staff wholly engaged, under competent direction, in controlling the fuel consumption. Such control ought not to be relegated to a member of the technical staff whose chief attention must be given to the supervision of machines or of operations in which the consumption of fuel is merely an incidental, and perhaps even subordinate, consideration. It should be borne in mind that our scientific knowledge regarding fuels and their combustion has developed so rapidly during the past 20 years that it has now become a separate branch of technology for which special training is required. Without such training the ordinary works chemist (and still more so the engineer) is not competent to handle the subject. The task of training a sufficient number of competent men is one that will tax to the utmost the resources of the various laboratories established within recent years for the special study of fuel technology at our universities, and the Government should be urged, as a matter of pressing and vital importance, to assist, by adequate financial support, the extension of such educational facilities. A great deal might also be accomplished by some co-operative or collective effort on the part of a group of works in one and the same neighbourhood. Such group of firms might well unite in establishing, for their joint benefit, a common fuel laboratory and staff. The increasing cost of coal, and the present serious fuel situation, will probably compel action along some such lines.

(11) The full accomplishment of all (or indeed any of) these reforms will demand much co-operative investigation and action throughout the whole industry. But the fuel situation has now become so serious in this country that the industry ought to cast aside sectional or individual interests or jealousies in a mighty and patriotic concerted effort to achieve the utmost efficiency and economy in its use of coal. It is a duty that it owes both to the present generation and to posterity. The British Association Fuel Economy Committee, on whose behalf and in whose name we speak, will feel that its work has not been in vain if, as the result of their reading and discussing this report, the leaders of the iron and steel industry inaugurate a movement that will not end until the "practical ideals" set before them in it have been achieved.

FUEL CONTROL IN METALLURGICAL FURNACES.*

By Sir Robert Hadfield, Bart., F.R.S. (Past President), and R. J. Sarjant, M.Sc.

Part I.—Design and Control of Furnaces.

I. Introduction.

The object of Part I of this paper is to discuss from the practical standpoint certain principles underlying the economical use of fuel in metallurgical furnaces, to emphasise the present insufficiency of scientific data for an effective determination of the distribution of heat units in them, and to indicate how far existing data can be applied in developing practical means of detecting and controlling avoidable losses.

With the first desirable essential that there should be consistent records of the furnace output, the temperatures attained, and the fuel consumption, must be combined an accurate knowledge of the thermal values of the fuel on a cost basis. A table of comparative fuel values is given in Table I, page 426, drawn up for current prices in Sheffield.

From this table it is evident to what extent certain fuels under prevailing market conditions have a start in the race. The last column of air values is given with the object of showing what volumes of air are necessary to produce the same quantity of heat from different fuels, for we have to debit against the fuel this waster of heat units in cases in which the air control is not closely watched.

II. Need for Compilation and Co-ordination of Scientific Data.

In all questions of efficiency in metallurgical furnaces there is an outstanding need for much further data with regard to the thermal measurements, which must serve as an effective aid to the task of tracking down the distribution of the heat units. Particularly is this the case with regard to the specific heats and heat conductivities of refractory materials. The latter were drawn attention to by E. Griffiths before the Faraday Society in 1917,† and the information he gave should serve as a useful guide. Other information of value on this and other questions relative to thermal measurements is to be found in J. W. Richard's "Metallurgical Calculations." Valuable assistance can be derived from such data as does exist if applied judiciously. Ultimate measurements must be based on actual experimental observations on the materials used. It is desirable, for instance, to base measurements of loss of heat from furnace walls on comparative laboratory tests of conduction and radiation phenomena made on representative materials, and due allowance must be made for the inevitable variations that occur in different consignments of material.

Then, again, existing information regarding specific heat and latent heat of change of state of metallic alloys leaves much to be desired. We have found that an approximate determination of the total heat of a metal can be obtained from the character of the heating curve.

III. Economical Combustion.

In dealing with the subject of gaseous fuel in the Presidential Address to the Society of British Gas Industries in 1918, one of us drew attention to its economic utilisation in industrial heating, and to stimulate investigation and interest in the subject offered a prize for the best essay on the use of gas in commercial practice. In the prize essay, which was adjudicated on by the Society of British Gases Industries,‡ Mr. F. W. Epworth stated that "much waste in the use of gaseous fuel . . . arises largely from lack of knowledge of the principles involved," and made one of the objects of his paper to set out the underlying principles which govern its control. Not the least useful of the information he gave was a series of calculations of waste heat values and theoretical calorific intensities of some typical gaseous fuels. Indeed it was a step in that compilation

* Paper read before the Iron and Steel Institute, on Thursday, September 18, 1919.

† "Thermal Conductivity of Materials employed in Furnace Construction," *Transactions of the Faraday Society*, vol. xii, March, 1917, page 109.

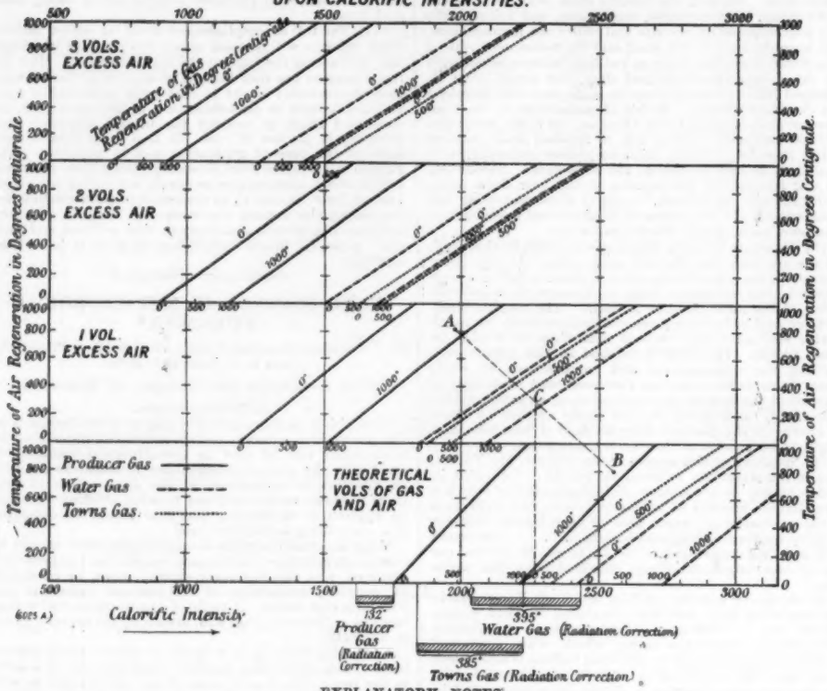
‡ Published in the *Gas Journal*, June 17 and 24, 1919.

of data which is needed, but fell short of best utility in not being presented in graphical form.

In order that the value of such work should not be lost sight of, we have drawn up from some of his tables the graphical chart (Fig. 1) of theoretical calorific intensities, showing the effect of excess air and temperatures of regeneration thereon, for three typical gases of the composition shown in Table II.

Consideration of this abstract notion of "theoretical calorific intensity" or the ratio of the net available heat to the thermal capacity of the combustion products, must be made with certain reservations, or it becomes deceptive and likely to lead to false conceptions of the heating effect of different gases.* Before it is possible to draw up a similar chart of true calorific intensities much fundamental research work needs to be done. A complete quantitative investigation of the thermal equilibria involved in the process of combustion is attended with considerable difficulties and opens up a wide field of endeavour, in which our own scientific men have not been inactive, its exploration dating from the time of Deville (1863). With proper regard being paid to its shortcomings, the presentation of such data has its uses from an instructive point of view and in stimulating interest in its present deficiencies.

Fig. 1. EFFECT OF EXCESS AIR AND TEMPERATURES OF REGENERATION UPON CALORIFIC INTENSITIES.


3 VOLS. EXCESS AIR
2 VOLS. EXCESS AIR
1 VOL. EXCESS AIR
Temperature of Gas Regeneration in Degrees Centigrade
Temperature of Air Regeneration in Degrees Centigrade
Producer Gas
Water Gas
Towns Gas.
THEORETICAL VOLS OF GAS AND AIR
Calorific Intensity
132° Producer Gas (Radiation Correction)
395° Water Gas (Radiation Correction)
385° Towns Gas (Radiation Correction)

EXPLANATORY NOTES.

The theoretical value for calorific intensity can be obtained by double interpolation.

Example: Required the value for producer gas when
(i) Temperature of gas regeneration = 900 deg.
(ii) " air " = 800 deg.
(iii) Excess air = 50 per cent.

Method: (i) In section for 1 volume excess air interpolate on 800 deg. air abscissa for gas regeneration temperature of 900 deg. So obtain point A.
(ii) Repeat in section for theoretical volumes for gas and air. So obtain point B.
(iii) Interpolate between A and B for 50 per cent. excess air. Thus obtain C = 2265.

TABLE I.—COMPARATIVE FUEL VALUES.

Fuel.	Calorific Value. B.Th.U. Gross.	Cost, August, 1919.	Thousand B.Th.U. per 1d. Cost.	Bulk.	Theoretic Volume of Air for Liberation of 1,000 B.Th.U. Cub. Ft. at 15 Deg. C.
	per lb.	per ton. s. d.		cub. ft. per ton.	
Coal.					
Anthracite (Welsh)	15,000	56 0	50·0	40·0	10·1
Bituminous hards (Yorks., Derby and Nottingham coalfields)	12,250	34 0	67·3	48·0	11·0
Bituminous nuts (ditto)	12,250	30 0	76·2	45·0	11·0
Coke.					
Foundry	13,500	66 3	38·0	65·0	10·3
Steel melting	13,200	64 0	38·5	70·0	10·5
Large gas coke	12,900	43 3	55·7	80·0	10·45
Breeze coke	12,800	47 9	50·0	58·0	10·5
Liquid Fuel		per gal.			
Petrol	20,000	2 8	4·5	25·0	9·85
Benzol	17,750	2 4	5·6	31·8	9·85
Paraffin	19,950	1 3	10·9	29·7	9·45
Heavy oil (blast-furnace neutral fuel oil)	16,000	0 6½	22·9	33·4	10·3
Gas.	per cub. ft.	per 1,000 cub. ft.*		Density Relative to Air.	
Town's gas	535	4 0	11·15	0·61	8·3
Water gas	310	0 11·5	27·0	0·53	7·1
Producer gas	165	0 4·8	34·4	0·88	7·6

* In a discussion recently before the Engineers' Society of Western Pennsylvania, Mr. A. E. Blake gave an estimate of the cost of blue water gas and producer gas, based on prices prevailing a year ago in America. For large sets he quoted the price per million British thermal units produced as 28·91 cents for water gas made in sets provided with waste-heat boilers, and 27·35 cents for producer gas. These figures correspond to a production of 79·1 and 85·6 thousand British thermal units per 1d. at the present rate of exchange.

TABLE II.

Gas.	Percentage Composition by Volume.						Calorific Value. B.Th.U. per Cub. Ft. at N.T.P.		B.Th.U. per Cub. Ft. Mixture for Theoretical Combustion.	
	CO.	CO_2.	$C_n H_m$ (i)	$C_n H_{2n} + 2$ (ii)	H_2.	N_2.	Gross.	Net.	Gross.	Net.
Producer gas	23·0	4·0	—	2·2	14·0	56·8	151	141	68·5	64·1
Water gas	42·0	4·0	—	0·5	51·0	2·5	326	299	99·0	90·7
Town's gas	17·0	3·0	3·0	24·0	41·0	12·0	509	459	98·9	89·2

* Taken as $C_2 H_4$. † Taken as CH_4.

With regard to the disturbing factors, the question of radiation from flame has been drawn attention to before the Institute by Professor W. A. Bone† at the autumn meeting in Brussels in 1913, and a very clear account of the subject is given in the brochure cited above.‡ We have applied the radiation correction after the manner developed by him for such conditions as the approximate data existing warrants. It is feasible to expect that at the higher temperatures radiation is considerably increased. Thus for a producer-gas obtained with a blast saturation temperature of, say, 55 deg., the theoretical flame temperature for combustion with 50 per cent. excess air and regenerative temperatures of 1,000 deg. is about 2,400 deg. C., whereas, according to Groume Grjimailo§ the effective flame temperature is more nearly 1,850 deg., a figure more in keeping with practical observations. This would entail a heat content of the flame 23 per cent. below that which would obtain under non-radiating adiabatic conditions.

This is not the occasion to enter deeply into the very complex theoretical considerations bearing on these reservations, but it may not be out of place to indicate the directions in which equilibria in flame tend to operate. With regard to the water-gas equilibrium,

$$CO_2 + H_2 \rightleftarrows CO + H_2O \ldots \pm 10 \text{ kg. C. units per gramme-molecule,}$$

which tends to limit the instantaneous development of heat, we have extended, on theoretical grounds, the constants determined by Hahn‖ to the higher limits of temperature. We also indicate at what temperatures the dissociation of H_2O and CO_2 would become appreciable where there no disturbing factors (Table III).

TABLE III.¶

Temperature.	Dissociation of H_2O and CO_2. H_2O $100x$.	CO_2 $100y$.	Equilibrium Constant. $K = \frac{[CO]\,[H_2O]}{[CO_2]\,[H_2]} = \sqrt{\frac{y^3(1-x)^2}{x^3(1-y)^2}}$
deg. C.			
1,500	0·3	0·7	5·20
2,000	2·0	8·2	8·10
2,500	9·5	36·5	11·70
3,000	23·0	70·4	16·5

Le Chatelier had shown** that the dissociation of CO_2 is only perceptible in melting furnaces and in ordinary flames, and is vanishingly small in the case of explosives. Moreover, at fairly high temperatures and normal pressures the law of mass action demands that the disturbing influence of dissociation may be entirely eliminated by the presence of a small excess of oxygen.

The size of the flame is undoubtedly influenced by the time reaction factor. The process of successive oxidation in conditions far from adiabatic is a characteristic of the "lazy" flame, described by Groume Grjimailo in the French of his translators as "douce et languissante," so much to be desired in low-temperature processes. Incidentally he points out that this flame must be obtained by a minimum use of excess air, whereas the frequent method employed is to obtain the lower temperature by undue use of air in excess and consequent distribution of the heat units to the atmosphere *via* the chimney. It is in such cases as this, when we come to coal-fired furnaces, where the skill of the furnaceman in the use of the damper means so much to the fuel consumption.

Fearing for the life of the roof of his furnace, the open-hearth smelter floods the furnace with air, and in order to pump sufficient heat units into the charge has perforce to use an inordinate quantity of gas. Indeed it is a *sine qua non* with some operators that the air valve should always be left well open, whereas the better method is to operate with less air and gas, so as to ensure a short, hot flame.

In all high-temperature processes, where turbulence can be brought about it should be, as it aids the inherent heat conductivity of the flame in developing the heat units at the point where they are most needed, namely in close proximity to the mass to be heated. Further,

* W. A. Bone, "Coal and its Scientific Uses."
† *Journal of the Iron and Steel Institute*, 1913, No. II, page 111.
‡ *Loc. cit.*, page 260.
§ "*Fours à Flammes.*" Translated by L. Douglatch and A. Rothstein. Dunod and Pinat, Paris, 1914.
‖ *Zeitschrift für physikalische Chemie*, vol. xliii, page 705, and vol. xliv, page 513 (1903).
¶ "Theoretical Chemistry," by W. Nernst (Macmillan and Co.); Bjerrum, *Zeitschrift für physikalische Chemie*, vol. lxxix, page 537 (1912).
** *Ibid.*, 1888, vol. ii, page 782.

the rate of heat transfer is proportionate to the square root of the gas velocity.

IV. DETERMINATION OF COMBUSTION EFFICIENCY.*

Attempts have been made, with a measure of success, to construct devices for the automatic control of the gas mixture in the case of burners for town's gas, and a number of suggestions have been made with respect to optical indication, measurements of gas flow, and what amounts virtually to analysis of the mixture. The obstacle which has first of all to be overcome in the control of flame mixtures from observation of phenomena exhibited by the unburnt mixture is the difficulty of obtaining a true sample. Many of the burners at present on the market only complete the mixing in the furnace chamber. Failing that, we have found that the only reliable method of determining the efficiency of combustion is to combine determinations of the CO_2 (and any unburnt gas) in the waste gases and waste heat temperature observations with a knowledge of the composition of the gas used, obtained from periodical gas analysis. From a chart compiled in the manner shown in Fig. 2 the waste heat losses can then be readily attained, and at the same time the efficiency of the combustion checked.

V. CONDUCTION AND RADIATION LOSSES.

In the method of tracking down the heat units delineated, having determined the waste heat losses and the useful heat conveyed to the material heated from its mean temperature and mass, there remains a large surplus of heat, the distribution of which it is desirable to know. From reasons already given, namely, the insufficiency of data, this becomes the most difficult matter, and only approximations can be made. Reliable means of determination of the inside and outside temperatures of the walls are not readily at hand, and the task becomes complicated by the uneven distribution of heat and any complexity of design. The absolute value of the heat conductivity of the materials of the walls is well nigh impossible to attain under the average works conditions. These are essentials necessary for any determination of the heat passing through the walls. The measurement of radiation losses by the application of Stefan's law is possible, given the temperature of the radiating surface. However, by a combination of the two methods a fairly effective method of approximations by graphical solution can be used. A series of graphs of the heat conducted through walls for different temperature gradients in terms of a standard thickness of firebrick of known conductivity are combined on the same diagram (Fig. 3) from the well-known relation :—

where K = coefficient of heat conductivity.
Q = quantity of heat passing in unit time across wall.
θ = temperature difference across the walls.
t = thickness of wall.
A = area of surface.

$$Q = \frac{A \theta K}{t}$$

Circular and irregular-shaped surfaces can be dealt with by applying integration formulæ.

Reading to the same scale of temperature, a graph of the radiation losses from the same surface (or a number of them, according to the various emmissivity constants prevailing) is prepared and drawn on a piece of tracing cloth. Since the following relation must hold, that—

Heat conducted through the walls = heat lost by radiation, &c.

the point of intersection of the two curves of heat of conduction and of radiation must indicate the actual heat loss. By setting the point marked x on the upper chart over, say, the approximate temperature of the inner wall and noting the point of intersection of the two curves concerned, the heat loss and the temperature of the external surface of the wall are obtained, and the right set of conditions has been chosen if the actual temperature of the external wall approximates to the value read from the chart.

The particular type of radiation formula used is that developed by Professor J. W. Hinchley in a course of lectures on Chemical Engineering at the Imperial College of Science and Technology, and is of the form :

$$L = a (T_h^4 - T_a^4) + b (T_h - T_a)^{1 \cdot 25},$$

Where L = total heat loss.
T_h = temperature (degrees absolute) of the hot surface.
T_a = temperature (degrees absolute) of the hot air.
a = Péclet or emissivity constant.
b = Constant dependent on atmospheric conditions prevailing.

At the same time it becomes possible to determine at once what saving of heat will follow the increasing of the thickness of the furnace wall by any other lagging material, and this information, combined with the cost of the extra material and the amount of "lighting up" gas needed to raise it to its temperature, will indicate what the economic dimensions should be. Further, the slope of the radiation curve for different emissivity constants will indicate the degree of any possible saving from the coating of the walls with special preparations, provided the value of this constant is known for the material from laboratory determinations.

VI. PRACTICAL APPLICATIONS.

With the heat balance of the furnace thus worked out, we are in a position to review the thermal economy of the whole furnace in relation to the special metallurgical demands of the process. What the saving is likely to be in any improved control of combustion is evident at once from the chart (Fig. 2), and in our review of the whole facts any possible changes in the design—for example, as to whether the volume of the combustion space is correctly related to the size of material heated, and to the conditions of combustion prevailing—are indicated, and the effect of these traced by a similar method.

A heat-distribution chart for a number of gas-fired furnaces is given (Fig. 4) by way of illustrating the method. By means of this chart it has been possible to foreshadow the only changes likely to result in fuel economy. Thus, in the case of the waste heat the possible saving was only in the region of 5 per cent. Reduction of the radiation loss would entail reconstruction of the furnaces in certain respects, or a modification of the metallurgical process. Experiments are being continued in the attempt to make practical use of this information in respect of flame control and the selection of refractory materials.

Finally the authors would emphasise the point that the economical utilisation of fuel cannot be brought about in a hurry. It can only be the result of long and patient labour, and the cordial co-operation of all associated with its use.

Our best thanks are due to Mr. J. B. Milne and to Mr. W. E. Parker for their kind help and suggestions throughout the investigations on which this paper is based.

PART II.—NOTE ON THE GENERAL POSITION IN REGARD TO ENERGY SUPPLIES.

Whether the future consideration of our fuel resources is to follow in the direction of a greater application of gaseous fuel or the development of a smokeless fuel together with an increase of the production of fuel oil from coal, or whether a greater proportion of raw coal is to be directly transformed into electrical energy, the call of the present time seems to be for a broad constructive view of the whole situation to be taken by those responsible for our industrial policy. The directing of conflicting interests in the channels of industrial progress calls for the application of a genius of organisation, that some of our friends, though not all our enemies, say we do not possess as a nation. It embraces a problem which is the paramount need for the moment of the world at large.

If they have not already done so, those interested in fuel problems ought certainly to study the excellent report of Messrs. Chester G. Gilbert and Joseph E. Pogue (of the Division of Mineral Technology, United States national Museum), "The Energy Resources of the United States: A Field for Reconstruction." This is one of the reports (Bulletin 102, vol. i) of the Smithsonian Institution, United States National Museum, on the mineral industries of the United States.

The joint authors of this contribution are to be congratulated on the excellent manner in which they have presented the result of their labours, which are dealt with in great detail, under the broad headings of "Domestic Fuel," "Petroleum," and "Power." An able summary shows the present position of the problem, so far as the above requirements are concerned.

The energy with which our French Allies have applied themselves to the problem of fuel economy is instanced by an admirable account of the Fuel Economy Service at the Compagnie des Forges et Acieries de la Marine et d'Homecourt by Mr. E. Damour, and published in the *Revue de Métallurgie*, March-April, 1918, pages 117 to 126, drawing attention to the great share that French savants and engineers have had in the pioneer work on which the necessary experimental calculations and observations of thermal values are based. Mr. Damour points out the material and technical difficulties which have to be faced, and outlines a scheme which has been in operation in the works of the company since 1912.

It is incumbent upon those of us in this country to do no less than our friends and to devote our full energies to the exploration of every source available for the conservation and utilisation of our fuel supplies.

BEIRA (SOUTH AFRICA) DISTRICT MINING.—According to *The South African Mining and Engineering Journal*, tin has been discovered in paying quantities at Inchofa, about 160 miles from Beira. At present the development of the work is in its elementary stages, but the prospects are good. Copper is being worked at Edmundian, near Umtali. The working of these mines is in the hands of a syndicate. In 1913, 4,816 tons of copper were obtained. In 1917, 307 tons, and in 1918, 207 tons, were exported The prospects for 1919 are good, and it is estimated that the mines should produce 80 tons per month. Up to the present the ore has been sent to Rhodesia for treatment. A new plant is, however, nearing completion, which will enable the syndicate to deal with the ore at Edmundian. In what is known as the Macequece Gold Belt, a considerable number of small mines are being worked for gold. At present the gold is chiefly obtained from surface washing. All rock and streams in this region bear traces of gold. The largest mine now working is the Andrada mine. Although no coal is being worked in the territory, it is certain that coal exists, though in what quantity has not yet been ascertained. It is said that a coalfield exists about 130 miles from Beira towards Chindio, on the Zambezi. Should this prove to be correct, the time may come when Beira develops into a bunkering port of note. The port of Beira is to a very great extent dependent upon the transit trade to and from Rhodesia for a large proportion of its prosperity. The transit trade of Beira is served by Rhodesia as far as Bulawayo, and also by the Belgian Congo.

* "Sir Robert Hadfield Prize Essay," by F. W. Epworth, page 22 (reprinted from the *Gas Journal*).

RELATION BETWEEN CO_2, EXCESS AIR AND HEAT LOST IN WASTE GASES.

Fig. 2.

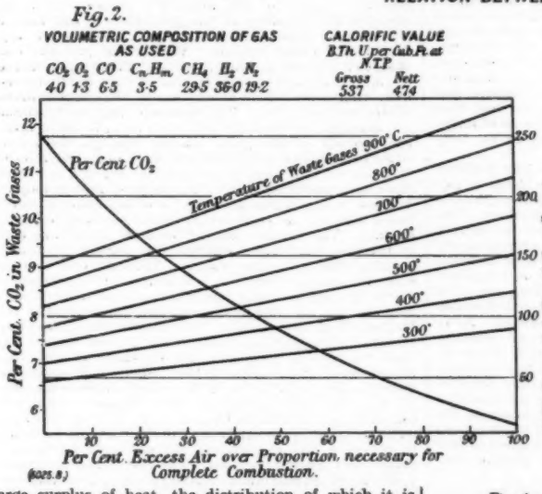

VOLUMETRIC COMPOSITION OF GAS AS USED
CO₂ O₂ CO CnHm CH4 H2 N2
4·0 1·3 6·5 3·5 29·5 36·0 19·2
CALORIFIC VALUE B.Th.U per Cub.Ft. at N.T.P.
Gross 537 Nett 474
Per Cent. CO₂
Temperature of Waste Gases 900° C.
800°
700°
600°
500°
400°
300°
Per Cent. CO₂ in Waste Gases
B.Th.U. per Cub. Ft. of Gas Burnt.
Net Available Heat Lost. Per Cent.
Per Cent. Excess Air over Proportion necessary for Complete Combustion.

Fig. 3.

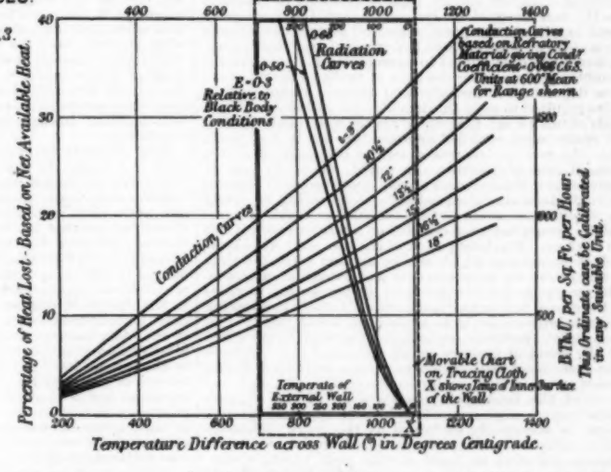
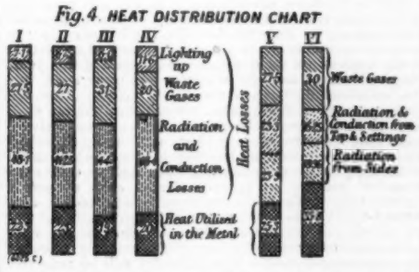

RADIATION LOSSES.
Coal Radiation Curves
E·0·3 Relative to Black Body Conditions
Conduction Curves based on Refractory Material giving Coeff. Coefficient 0·0·8 C.G.S. Units at 600° Mean for Range shown.
Conduction Curves
Movable Chart on Tracing Cloth. X shows Temp. of Inner Surface of the Wall.
Temperate of External Wall
Percentage of Heat Lost - Based on Net Available Heat.
B.Th.U. per Sq. Ft. per Hour. This Ordinate can be Calibrated in any Suitable Unit.
Temperature Difference across Wall (°) in Degrees Centigrade.

Fig. 4. HEAT DISTRIBUTION CHART



FUEL ECONOMY IN THE GERMAN IRON AND STEEL INDUSTRY.

*Report on the Present Status of Fuel Economy in the German Iron and Steel Industry of the Occupied Territory on the Left Bank of the Rhine.**

By COSMO JOHNS (Sheffield) and LAWRENCE ENNIS (Middlesbrough).

Introduction.—This report is a statement of facts and inferences based on observations made in the occupied territories on the left bank of the Rhine by the authors when members of a Commission appointed by the Government to investigate the German iron and steel industry in the occupied territory, and to report on certain subjects. That report has now been communicated to the Government. The present report, for the presentation of which permission has been obtained, has been prepared at the request of No. 1 Committee of this Institute. It was felt that a reasoned statement of the present status of fuel economy in the areas that had been visited would serve a useful purpose in not only describing such advances as had been made, but also as indicating the direction in which further progress appears to be trending. It is necessary to make it quite clear that the war period was, for the iron and steel industry in the areas visited, a time which can best be described as that of arrested development. Hostilities, and especially the blockade, had created conditions that gave rise to difficulties which taxed the resources of those responsible for the direction of the iron and steel works to an extent scarcely realised in this country. The lack of lubricants and essential non-ferrous metals, the over-strained transport system, rapidly declining in efficiency as the war dragged on its course, and the inadequate food supplies in the great industrial centres contributed to a state of affairs which left the iron and steel manufacturer too preoccupied in overcoming his ever-present troubles to have either the time or facilities to undertake new departures in metallurgical practice except such as were required to meet the demands for military products. This is not to say that no advances were made or that no plants were modified or extended, but it does mean that the war period was a serious interruption in the normal rate of progress. It would, therefore, lead to serious error if this report merely described such systems or methods as were observed without indicating, as clearly as the evidence would justify, the lines on which progress will be attempted when established conditions permit this to be done. The long period of the war must have been rich in experience which can be applied when the time is opportune for improvements and extension of plants. The serious, and to a large extent the permanent, increase in the cost of fuel on the Continent will hasten the adoption of such improvements as experience would justify. In this report, therefore, we have not hesitated to lay stress on the trend of progress as we conceived it. We have also mentioned well-known proposals, advanced during recent years, which, so far as we could learn, had not received the favourable consideration of the German metallurgical engineers. This lack of apparent interest might be adequately explained by the grave difficulties under which the industry laboured during the war. During our visit in April of this year Lorraine was technically, occupied German territory, though it was obvious to all of us that France had resumed her old position there. Since that visit the territory has been definitely restored to France. It was thought, however, best to retain the title of this report as it now stands. by occupied territory is meant all that region that lies between the frontiers of Holland, Belgium and France, as they existed before the war, and the River Rhine. It contains some of the most recently designed plants and is typical of the most advanced German practice.

Raw Materials.—In the iron and steel industry the characters of the ores and fuel used are important factors when considering the question of fuel economy, and a knowledge of the chemical and physical properties of the principal raw materials is necessary before any useful comparison can be made between one industrial centre and another. The source of iron ore is the great Lorraine ironfield now in the effective occupation of France. The ores are low in their iron content but easily accessible; they are concentrated in ferruginous beds of varying qualities and changing in composition as they are traced laterally. By making a suitable selection from different beds, or localities, self-fluxing mixtures can be obtained, as is the general practice. The average iron content of the mixture of ores being smelted during the war and at the time of our visit was less than 30 per cent. The composition of the ores is shown in Table I at the end of this report. It is a very reasonable assumption that at least 3½ tons of iron ore are required for each ton of pig-iron made. Most of this ore is now mined, only a comparatively small proportion of the output being obtained from open workings. The users of Lorraine ore have therefore no particular advantage compared with those who use the English Jurassic ores, which have a very similar range of composition and can still be obtained in large quantities from open workings. Except for the works in the Saar Valley the iron works visited used Westphalian coke. This means that for the production of a ton of pig-iron the ratio of the weights of iron ore and coke required would be nearly 3 : 1, and it is not surprising to find the most important iron and steel works clustered round or on the ironfield. Nearness to the source of fuel would not compensate for the heavy charges incurred by moving the greater weight of ore. Hence we find few works, except on the Saar coalfield, with their own coke ovens. Fuel economy then resolves itself into making scientific use of the coke charged into the blast furnace. This dependence of the great works clustered on or round the Lorraine ironfield, of Westphalian coke is a striking feature of the iron industry in the areas dealt with in this report. In one works only in Lorraine did we find coke ovens, and there they used Saar coal with a certain percentage of Westphalian coal mixed. In the Saar Valley Saar coal was used, and every works visited had its own coke ovens, but with one exception some Westphalian coal was used in the coke-oven charge. One works was using all Saar coal for its coke. In no case did we find Saar coke carried any distance. Its friability and consequent breakage during transport was an accepted conclusion. We found, too, that Westphalian coke was always imported by rail. Water carriage involved so much extra handling that the reduced freight charges did not compensate for the increased waste by breakage. All this has some bearing on the question of fuel economy. The cost in April this year of producing a ton of pig-iron at one of the largest works we visited was distributed as follows:—

	Per Cent.
Iron ore	14·5
Coke	54·0
Labour and on charges	31·5
Total	100·0

It is easy to see that economies in fuel consumption would be the easiest road to reduced production costs, and it is not surprising that fuel economy had received much attention and, with the rapidly increasing cost of fuel, that attention will not be relaxed in the future. Although most of the works visited are on the ironfield and ore can be brought on to the storage bins by aerial ropeway, it had been found expedient to erect storage bins with capacities of from 15,000 tons to 25,000 tons, with separate bins for the different qualities of ores. These large reserves of ores at the iron works constitute a factor in the regular working of the blast furnace that should not be overlooked. It is noteworthy, too, that they were generally covered in. This provision of large, well-designed storage bins seemed to us to be very significant.

Fuel Economy in Pig-Iron Production.—The problem of fuel economy in the iron and steel industry is not completely envisaged until it is realised that pig-iron is not the only useful product of the blast furnace. The gas produced in such prodigious quantities is not merely a lean fuel gas that can be utilised. It is, when properly cleaned, the ideal fuel for internal combustion engines. It stands much compression, if sufficiently cooled, without danger of premature explosions. Its working pressures are moderate, and its use involves no particular difficulties in the design of engines of considerable power. As it must be produced in the course of the normal working of the blast furnace, and as no metallurgical change in blast-furnace practice that would enable the gas to be used in the furnace itself appears to be commercially possible we are in this position: the combustible gas must be produced and is as much a product of the furnace as the pig-iron. It is in the direction of utilising to its fullest possible extent the fuel gas produced that progress in fuel economy lies, and it is here that German practice has concentrated its efforts.

Just as we have already described the war period in the German iron and steel industry as one of arrested development, so now we describe the industry in the areas we visited as one in a state of suspended animation at the time of our visit, which was in April of this year. War had ceased and the armistice had intervened, but the industrial dislocation was at its height. Iron ore did not travel to Westphalia, nor did Westphalian coke come to Luxemburg or Lorraine. With a comparatively small number of furnaces in blast, and having regard to the difficulties encountered during the war, it would serve no useful purpose in tabulating data such as coke consumption per ton of pig-iron during such abnormal periods only. We have therefore cited pre-war and present-day values; but we should point out that the use of lean manganiferous slags, in place of the rich manganese ores formerly imported, seriously affected the coke consumption. This difficulty will be removed when imports are resumed, and though, from the analyses we saw, it appeared that the iron content of the iron ores used was appreciably lower during the war, and since, than those formerly mined, we conclude that when conditions become more normal these works will once more smelt their pig-iron on a coke consumption little, if any, higher than before the war. These pre-war figures, though not remarkable, are very good considering the lean character of the ores, which, we might add, were never calcined. The blast-furnace coke consumption is shown in the following table:—

Works.	Area.	Coke Consumption. Kgs. per Ton of Pig-Iron.	
		Pre-War.	April, 1919.
"Arbed" Dudelange ..	Luxemburg ..	1,150	1,400
Esch-Belex	,, ..	1,000	1,250
Differdange	,, ..	—	1,200
Moyeuvres	Lorraine ..	—	1,400
Rombas	,, ..	—	1,300
Hayange	,, ..	—	1,125
Uckange	,, ..	1,120	—
Carlshütte	,, ..	1,150	1,350
Maizieres	,, ..	1,150	1,350
Burbach	Saar Valley ..	1,250	1,430
Dillingen	,, ..	1,100(?)	—
Volklingen	,, ..	—	1,500
Neunkirchen	,, ..	—	1,400

A very interesting departure was noticed in the Rombas works. The blast furnaces were provided with four or five stoves, as was the general practice in the works we visited, but a new furnace, just completed, had only three. There were, however, two recuperators added which utilised the heat in the products of combustion from the stoves to pre-heat the air used for the combustion of the gas used for heating. As an attempt to conserve some of the heat in the products of combustion coming away from a stove on gas, the recuperator was very suggestive. The products of combustion passed through tubes while the air for combustion passed round them.

Gas-Cleaning Systems.—There was evidence in every place we visited that the importance of the effective cleaning of the gas was fully realised, and effective cleaning begins after the gas leaves the ordinary dust-catcher. We did not observe a single instance where uncleaned gas, using the term in the sense described above was used for stoves or boilers. Some system—wet or dry—was almost always used to reduce the dust content of the gas down to about 0·1 gramme per cubic metre before it was used for any heating purpose whatever. There was no general agreement as to what was the best method to employ. We found that wet towers and fans and the Zschocke wet system were common, but we also saw many installations of the Halberg-Beth dry cleaning system. In fact, dry cleaning was the general practice in the Saar Valley. But whether wet or dry systems were employed, the aim in every case was to reduce the dust content to as near 0·1 gramme per cubic metre as possible, and we were satisfied that this was realised in most of the works we visited. It is this effective first cleaning of the gas before it was used in stoves or for boilers that rendered available such a large surplus for other services. With clean gas the consumption for stove heating is reduced, flame temperatures are higher, air and gas can be used in more nearly correct proportions, while heat absorption by the chequer bricks will be more effective. The absence of dust would enable the passages between the bricks to be reduced in area; the velocity of the gases passing through the stoves could be increased and higher efficiency obtained, a result that has not only been proved experimentally, but could have been predicted from a knowledge of first principles. We saw in one works an example of air under pressure being used for the combustion of the gas used for stove heating. The second cleaning for such gas as was used in internal-combustion engines was almost invariably accomplished by Theisen washers. These not only brought down the dust content to as low as from 0·001 gramme to 0·003 gramme per cubic metre, but also served to finally cool the gas. At one works we were informed that the Halberg-Beth dry cleaning delivered the gas quite clean enough for gas engines, but that the Theisen washer was used for cooling purposes. At the time of our visit trouble was experienced with the Halberg-Beth apparatus owing to the inability to obtain suitable textile material for the bags, and on that day the Theisen washer was certainly contributing to the cleaning. Enough has been written, however, to make clear the importance attached to effective first cleaning of the gas used for stoves, boilers and heating furnaces. The cost of fuel compared with that of ore and labour was the primary incentive and indicated the direction in which economy might best be achieved; but it was effective cleaning of the gas that rendered it possible to translate into works practice the well-known principles that govern the scientific utilisation of gaseous fuel with such general success.

Rôle of the Large Gas Engine.—Nothing that we saw during our visit was more suggestive or instructive than the use made of large gas engines. The large central stations with 10, 12 or more gas engines of from 1,500 h.p. to 5,000 h.p., visited at so many works were eloquent testimony to the value of the internal-combustion engine for the utilisation of fuel gas. Blowing engines for the blast furnaces, for the Bessemer converters, and for the generation of the electric power were nearly always gas-driven. The more modern the works, the more were large gas engines used. The reason is not by any means obscure, for though the steam turbine of from, say, 10,000 h.p. to 50,000 h.p., such as is used in modern electric power stations, have a thermodynamical efficiency approaching that of the medium-size gas engine (and where prime movers in such large units are required, has the field to itself), yet, for the units favoured in iron and steel works for blowing engines or electric generators the gas engine is not only the most efficient, but it uses the fuel gas that is normally and necessarily produced by the blast furnace—a fuel on which the only real cost incurred is that for collecting and cleaning it. Starting with the cleaned gas the alternatives are steam raising and using the steam in turbines, or using the gas in internal-combustion engines. Here the overall efficiency from fuel to power generated is greatly in favour of the gas engine. The large installations in nearly every works we visited were convincing proof that the large gas engine using cleaned blast-furnace gas was a reliable prime mover. Table II, at the end of this report, shows the installations of large gas engines at works. It is by the fullest possible use of blast-furnace gas in large gas engines for the compression of air for blast furnaces and Bessemer converters and the generation of electric energy for transmission to rolling mills, and other steel works plant, that fuel economy can be secured, for in this way, and this way only, can a considerable surplus of gas be obtained for such steam raising as may be found necessary and for furnace heating. This was the policy of the works we visited, and the more modern the works, or the more recent its reorganisation, if an old one, the more completely was it carried out. [Yet the large gas engine did not suffice to meet all the demands made on it. It was excellent as a blowing engine either at half an atmosphere for the furnaces or 2½ atmospheres for the

* Paper read before the Iron and Steel Institute at Sheffield, on Thursday, September 18, 1919.

converters; but the gas-driven electric generators do not respond to the fluctuating demands from the steel work and the usual practice was to install some steam turbine-driven generators to assist the gas-driven generators, and thus form an elastic combination. But the gas engine was the predominant partner, and it was interesting to note, as a sign of what we may expect in the near future, that at the Volkingen works in the Saar Valley a waste-heat boiler had been installed to utilise the sensible heat of the exhaust gas of a 3,000 h.p. gas engine, and so successful had been its performance (said to be 13 cub. m. of water evaporated at 15 atmospheres pressure with considerable superheat) that a second boiler was being put down. Attention has been directed by both Bone and Dugald Clerk to the fact that the gas engine, in addition to its high efficiency as a heat engine, still rejects in its exhaust gases a considerable proportion of the heat of combustion of the fuel it consumes. The example we saw of the successful utilisation of this waste heat in the immediate vicinity of the power-house where the turbines were installed was convincing evidence that effective use can be made of the heat in the waste gases from large gas engines. If at the same time the cooling water of the gas engine be used as feed water for the waste-heat boiler we should have a combined efficiency unapproached by any other prime mover. That this is the direction in which further economy in the consumption of fuel can be obtained is clear from the general principles involved and the examples we have cited. The more the gas engine can be utilised for power and blast production, and the less the call on gas or coal-fired boilers, the greater will be the economy measured in fuel consumption—from ore to finished steel—per ton of product, for it would follow as a consequence that more blast-furnace gas would be available for furnace-heating in the steel works.

Metallurgical Considerations.—It is perhaps desirable that we should at this stage briefly refer to the metallurgical processes other than the operation of the blast furnaces. It was only exceptionally that we saw blast furnaces without a steel plant, and it was still more exceptional to find a large steel works that did not possess its own blast furnaces. This combination of steel works and blast furnaces is the normal unit for the production of commercial steel in the areas we visited and the average capacity of that normal unit can be approximately stated as 400,000 tons of pig-iron per annum. Many of the plants seen were considerably larger than that. Without exception the basic Bessemer process was employed for the conversion of the greater portion of this liquid pig-iron into steel. The basic open-hearth furnaces which dealt with the scrap produced in the mills used from 20 per cent. to 25 per cent. of pig-iron in their charges, and were thus able to work on a low fuel consumption—about 250 kg. per ton of ingots made would probably be an average of the coal used—while the few electric furnaces used liquid steel from the converters as a rule, though we did see open-hearth furnaces used for supplying raw liquid steel for the same purpose. This combination of Bessemer converter, open-hearth furnace, and electric furnace—each process working under the most favourable conditions and turning out the class of steel best suited to it—was another factor tending to fuel economy in steel conversion. The basic Bessemer process requires for its successful operation a pig-iron rich in phosphorus and low in silicon and sulphur. The phosphorus is supplied by nature in the Lorraine ores. Low silicon and sulphur is the reward of good blast-furnace practice.

That pig-iron running well below 1 per cent. in silicon and from 0·06 to 0·07 in sulphur was being regularly made was evident from our investigations in the works visited; it was abundantly confirmed by the absence of active mixers—that is, of mixers in which desiliconisation is carried out. The mixers we saw were mere receptacles for holding the surplus liquid iron. The only heating attempted was by means of blast-furnace gas, or, more rarely, coke-oven gas introduced by means of a simple pipe through openings in the top of the mixer. The object was to assist in keeping the slag liquid. A further confirmation was found in the fact that at some works visited they were using liquid iron, direct from the blast furnace, in the converters, owing to the shortage of iron. The cost of putting iron through those mixers would be negligible.

We have referred to the favourable conditions under which the open-hearth plants were operated. The bath areas were large for the nominal rating of the furnaces employed, and the charge, which was rapidly melted down, would be ready for tapping when melted. The fuel used was producer gas in every place we visited. but in more than one works preparations were being made for using blast-furnace gas enriched with coke-oven gas. This enrichment would not be possible in works that did not possess coke-ovens as part of the unit, but when the use of blast-furnace gas for heating open-hearth furnaces becomes established, as there is every possibility, the enrichment can be effected by other means which will suggest itself to the metallurgical engineer. The composition of the blast-furnace gas was on an average:—

	Per Cent.
CO_2	10
CO	28
H	4

Very little enrichment with heavy hydrocarbons would convert this into a most useful gas for open-hearth work. The electric furnaces we saw do not call for any special comment. Using, as they generally did, liquid converter steel, the power consumption was in the neighbourhood of 200 units per ton, depending on the class of steel made. This is the normal consumption for electric furnaces using liquid low-carbon steel as a charge.

A discussion as to the relative merits of basic Bessemer and basic open-hearth steel would be out of place in a report such as ours, and would take us outside its limits; but it should be pointed out that the primary fuel, other than the carbon, is the phosphorus in the iron, and this on being oxidised and fixed by the slag as lime phosphate, is a fertiliser of great commercial value. The secondary fuel is the fuel gas used in the gas blowing engines.

Having regard to the more favourable yield of the basic Bessemer process compared with the acid process, it stands as the most economical in fuel consumption of any known process for converting pig-iron into steel, and makes the smallest demand on the available supply of surplus blast-furnace gas.

Reheating Fuel.—It is the great advantage of a large steel plant, whether the Bessemer or a mixed plant of Bessemer and open-hearth be operated, that a constant, or nearly constant, supply of hot ingots is available, and the reheating problem lends itself to a simple solution. In the works we visited there were large numbers of unheated soaking pits supplemented by some which were coal or producer gas fired. It was significant that in more than one works preparations were being made to use regenerated blast-furnace gas in the fired soaking pits, and some were already doing it. In the Saar Valley a mixture of blast-furnace and coke-oven gas was considered the most suitable fuel for continuous and other heating furnaces. The war has no doubt hindered the more general adoption of these obviously sound proposals, but the restoration of more stable conditions will hasten the change. From this it will be seen that where solid fuel was used on grates or in gas producers, steps were being taken to use regenerated blast-furnace gas. For all the heavier products the initial heat of the ingot as withdrawn from the soaking pit was sufficient, and it was only with the small billets required for rolling into wire rods or small sections that a second heating was necessary. This was only rendered possible by the admirable lay-out of the mills; the ordered sequence of operations and the small loss of time in effecting transfers from one mill to another. The plate rolling mills seen used single ingots for each plate, and rolled down direct at a high speed from one heat. The small number of reheating furnaces, other than the soaking pits of which many were unheated, seen even in the largest works, was most significant. Solid fuel, in addition to its initial cost, involves considerable charges for handling in the works and the removal of ashes. Its burning on grates or in gas producers is costly both as regards the labour required and maintenance of the plant. It was not surprising to find surplus blast-furnace gas taking its place.

Power Consumption in Steel Works.—The rolling mills and auxiliary machines are large consumers of power, and therefore of fuel. The internal-combustion engine, despite its high thermodynamical efficiency, is not available, owing to its proved inability to meet, when directly coupled, the rapidly fluctuating demands of a rolling mill. The electric motor helps to get over the difficulty to a considerable extent, for the central power station, with its gas-driven generators and steam turbines, has less violently-fluctuating demands to deal with. It would, we consider, be generally agreed that mills of 36 in. diameter and under can be economically driven electrically, while for the smaller machines electrical power would always be preferred. It is when the large blooming mills come to be considered that diversity of opinion would become apparent. The weight of evidence as shown by current practice, was distinctly against the electrical driving of such large mills under the conditions that prevail in the areas visited, but the objections seemed largely based on the rapid and considerable variations in the power consumption of such large mills. This rapidly-varying load would perhaps impose too heavy a burden for the power station of a single works, even of the capacity we are describing, to carry, but the linking-up of neighbouring power stations such as we found was the case in Luxemburg would be an obvious remedy. It may be that we shall have correctly divined the direction in which steel works practice will trend if we consider the arrangement of the great Hagondange works completed by Thyssen, near Metz, just before the outbreak of war; where the steel works is completely electrified and the large blooming mill has a 16,500 h.p. motor at each end of the rolls, as a mile stone on the road of steel works progress. We must, however, put on record the fact that the majority of mills we saw were steam driven, the steam being largely produced in gas-fired boilers, though some coal-fired boilers were always used. The engines were, however, in nearly every case tandem compound condensing, with a central condensing station.

Little-Known Factors.—It should not be overlooked that the German iron and steel industry was described by us as in a state of suspended animation during our visit, so far as advances in fuel economy is concerned. We can see in the great Esch and Hagondange works the pre-war ideals realised. What would have taken place in other works had the war not interrupted normal progress can only be inferred from such tentative attempts as we have described, and by a consideration of the general principles involved. The cost of fuel has increased considerably throughout Europe, and much of this increase is permanent. Fuel economy, if urgent before the war, has now become the one problem, above all others, demanding attention. It is obvious that it must be engaging the earnest attention of the people who, before the war, had such a firm grasp of the principles involved. But before we proceed to discuss the observations we made and the tendencies we inferred, reference should be made to certain proposals which have been made in technical literature but have not yet established themselves in iron and steel works practice. These are: (1) The electrostatic process for the precipitation of dust or fume from gases; (2) enrichment of the air blown into the blast furnace with oxygen, and (3) the conservation or utilisation of the surplus gas at week-ends when the steel works are idle. The greater the economy affected in the use of blast-furnace gas, the more urgent will be the necessity for dealing with the still larger volume of gas that will be available at the week-ends. We can at once say that, with reference to (1) and (2), we failed to learn that these proposals had been tried or their trial even contemplated. The electrostatic process was devised by Professor Cottrell to remove the flue dust or fume in the voluminous output of waste gases in certain non-ferrous smelting operations. Once its virtues were recognised its adoption has made remarkable progress, and the days of the old bag systems for filtering the dust from the gases seem numbered. The bag system is expensive to erect and to maintain. It is but natural that the application of the Cottrell system to the cleaning of blast-furnace gases was suggested, and it is understood that experiments are in progress in England. If successful, there should be a wide field open for a system with so many advantages, and the Halberg-Beth system would then be superseded, just as its prototype, the bag system in the non-ferrous smelters, has been. Its great advantage would be that it could be used for gases much too high in temperature for the use of textile material such as is used for bags. Even if adopted, however, it would still be necessary to use a final washer, such as the Theisen, for the cooling, if not the cleaning, of the gas used in the internal-combustion engines. A further advantage would be that there would be no considerable cooling of the gas used for stove heating or boiler firing, except that lost transmission. It is hardly to be expected that, in the works we saw, the wet or dry systems erected at such a high cost would be pulled down for another system, but in a country where such elaborate cleaning plants do not exist the experiments we have referred to deserve being watched with interest. They will certainly not be overlooked in Germany. During recent years tentative proposals have been made to enrich with oxygen the air used in metallurgical smelting processes. So far the proposals are based on theoretical consideration, but it is reasonably certain that if tried the change in the equilibrium conditions of the blast furnace would be startling and favourable to fuel economy. The proposals have been received with much interest as indicating a profitable field for exploration. It had been reported before the war that a Belgian works had gone further than merely contemplating such experiments, so it was interesting to note that the works we visited had taken no steps, so far as our observations went, in attempting experiments in this direction. These proposals, though based on sound principles, have, in the past, been hampered by the cost of separating the oxygen from the mixed gases of the atmosphere. Theoretically, seeing that air is a mechanical mixture of gases, the power required to effect separation is small and can be calculated from accepted thermodynamical principles. The two leading commercial systems, despite recent improvements, have rather low efficiencies compared with the theoretical possible. It is now known that important advances have been made, and a new cycle developed, in America, as a result of the work done in the extraction of the once rare gas helium from natural gas in an attempt to provide helium for the airships of the British Admiralty and thus substituting a non-inflammable gas, only a little inferior in lifting power, for the easily-ignited hydrogen. Not only was the attempt successful beyond the most sanguine expectations, but in all probability a most useful improvement in methods of separating other gases from gaseous mixtures has been made. So far as this report is concerned, it is sufficient to say that we failed to notice any attempt to use enriched air in any metallurgical processes. The only suggestion we heard for utilising the surplus week-end gas was to erect a large gasometer for its storage. This is neither original or is it the only available method.

TABLE I.—*Lorraine Iron Ores.*

Works.	Average Iron Content of Ores used April, 1919.	General Average Composition of Ores.					
		Calcareous.			Siliceous.		
		Fe.	CaO	SiO_2	Fe.	CaO	SiO_2
Carlshütte ..	30 per cent. Fe						
Hagondage ..	30 ,, ,,						
Volklingen ..	25 ,, ,,						
Knutange ..	28 ,, ,,						
Hayange	28·5 ,, ,,						
Moyeuvre ..	32·5 ,, ,,						
Dudelange ..	26·5 ,, ,,						
Adolf Emil (Esch)	26·5 ,, ,,						
Average ..	28·5 ,, ,,	27·5	19·0	7·5	31·0	0·0	17·5

Summary of Conclusions.—This report would not be complete if we did not, as a result of our study of the present status of fuel economy in the works visited, put on record our conclusions as to the possible and most expedient lines on which attempts to still further promote fuel economy in iron and steel works should be made. We have already indicated what has actually been accomplished, and noted the various lines on which further work was being directed. Our own conclusions may be summarised as follows:—

1. The blast-furnace gas should be cleaned, without loss of sensible heat, if the conditions render it possible, until the dust content is at least as low as 0·1 gramme

TABLE II.—EXAMPLES OF INSTALLATIONS OF LARGE GAS ENGINES.

Works.	Number of Blast Furnaces.	Gas Driven.			Steam Plants.
		Blast-Furnace Blowing Engines.	Converter Blowing Engines.	Electric Generators.	
Hagondage	6	6– 1,500 h.p. each ..	2–5,000 h.p. each ..	12–2,500 kw. to 3,000 kw. each	Additional in all cases.
Knutange	10	9– 2,000 h.p. each ..	2–5,000 h.p. each ..	3– 2,800 kw. each .. 2– 1,100 kw. each	
Rombas	6	8– 2,000 h.p. each ..	1–6,000 h.p. each .. 2–4,000 h.p. each	3– 4,000 kw. each ..	
Differdange	10	8–14,000 h.p. total ..	—	12–20,000 kw., total ..	
Adolf Emil Hütte ..	6	8– 1,400 M³ air capacity each	—	9– 1,400 kw. to 1,500 kw. each	

per cubic metre. It is only when this has been done that the gas can be used economically for any purpose in iron and steel works practice. It is only thus that any useful surplus can be obtained for use in the steel works. Gas intended for use as fuel in internal combustion engines should, of course, be still further cooled and cleaned.

2. All power, whether compressed air for blast furnaces or converters, or electric energy, should be generated in gas-driven prime movers with only such steam turbines as are found necessary to deal with fluctuating loads. As much steam as possible should be furnished by waste-heat boilers attached to the large gas engines. These waste-heat boilers should be of the fire-tube type, not water tubes.

3. If the linking-up of the power stations of neighbouring works is possible, then the whole of the steel works should be electrically driven.

4. Cleaned blast-furnace gas, of the standard suggested in paragraph 1, should be the principal fuel employed in melting and reheating furnaces. The attainment of sufficiently high temperatures in open-hearth practice can be secured by enriching the available blast-furnace gas with either coke-oven gas or with some fuel rich in hydrocarbons.

These four conclusion of ours would reduce the number of steam boilers to a minimum. Even if compound condensing engines be preferred for the larger mills, most of the fuel for the extra boilers required would be cleaned blast-furnace gas, but it would be necessary to burn that gas under proper conditions and to correctly adjust the gas-air ratio. In either case the consumption of coal would be reduced to a figure that would be inconsiderable, if not negligible. The great works at Homécourt, just inside the old French frontier not far from Metz, only used about 40 tons of coal per 24 hours before the war for its large output. Here we have an actual example of a negligible coal consumption. The coke used in the blast furnaces produced enough gas to furnish practically all the other fuel required in the iron and steel works. It would no doubt be preferred to install a few efficient coal-fired boilers for emergencies, but coal firing for any purpose in a works such as we are describing would be on a very small scale. It is not always recognised that the modern blast furnace is the most efficient gas producer in existence to-day, and that the gas produced is the ideal fuel for the most efficient type of prime mover that we have available. In a district where there was a large demand for electric energy, it might be profitable for the steel works to sell it and use solid fuel in the works for heating or steam raising, but this would depend on the local demand, and its expediency would be decided by local conditions.

But before all this can be realised there are some other conditions that must be met. If cheap basic steel is to be made and fuel economy attained, it is absolutely necessary that the pig-iron should be within the required limits of silicon and sulphur and should be regular in composition. This can only be done when there are ample supplies of iron ore available in the furnace bins, so that regular working of the furnace can be ensured. The plants we visited in the occupied territory were producing iron of regular composition that could have been, and was in some cases, taken direct to the converters.

The mixers were, so far as any serious consumption of fuel was concerned, unheated. But the blast-furnace plants were admirably equipped with ample stove power, clean gas, and covered, in bins of large capacity for the separate storage of the various ores used. It would not be reasonable to demand a similar quality of iron from a plant less adequately equipped. It would also be necessary to so arrange the steel works that there should be no hindrance to the movement of the steel from soaking pits to the hot bank, so that the amount of reheating was reduced to the minimum. Thus far we have only, in this summary, dealt with well-known and used systems and methods, and have shown that within the limits of those conditions the consumption of fuel, other than the coke used in the blast furnace, can be brought down to a negligible quantity, but it involves the use of the basic Bessemer process on a large scale for converting the pig-iron into steel. Other processes would admittedly result in a higher fuel consumption. But the possibilities of further advances in fuel economy have already been mentioned, and if the newer proposals have not reached the status of accepted works practice they are at least soundly based on known principles. They require investigation on an adequate scale, and this could best be carried out on co-operative lines. We have not in this report done more than mention the few suggestions made for using coke-oven gas in steel works. We were informed of cases where the gas was, in view of its value owing to its high calorific power, sold for distribution as a lighting gas in the neighbourhood. This seems to us to be the best method for its disposal. It is not so suitable as blast-furnace gas for use in large internal-combustion engines. The advantage of installing coke-ovens near an iron and steel works would not appear to be as considerable as is sometimes thought, and certainly would not justify the extra charges involved in bringing coal instead of coke over long distances. There would be some advantage in avoiding breakage during transportage when the coke was friable.

The facts on which we have based this report are the result of the diligent labours of all our colleagues on the Commission, and especially Sir W. J. Jones, K.B.E.; Mr. R. C. Harding and Mr. P. S. J. Cooper of the Metz party; and Dr. F. H. Hatch, Mr. J. Henderson, and Dr. Mather of the Cologne party. To all of them we desire to express our obligations; their tactful inquiries and keen observations are largely responsible for such merit as this report may possess, but the authors alone must be held responsible for the inferences made and conclusions arrived at.

CATALOGUES.

Wireless Code.—A new international code is announced by the Marconi International Code Company, Limited, Strand, W.C. 2, printed in English and eight other languages.

Electric Transformers.—Self-cooled transformers of single-phase shell type and forced cooled transformers of single and three-phase shell and core type, both oil immersed, are illustrated with some text details in catalogues received from the British Westinghouse Company, Limited, Trafford-park, Manchester.

Electric Fuses.—The time-limit fuse, explained in a catalogue from the British Thomson-Houston Company Limited, Rugby, is a device for delaying the action in an oil switch so that momentary faults or temporary overloads may not disturb the circuit. These are now made in much smaller sizes, with reliable fusing points, than was formerly practicable.

Marine Paint.—An anti-corrosive and anti-fouling composition is now being made in large quantities by Graphite Products, Limited, 220, Queen's-road, Battersea, S.W. 8. Compositions for this purpose were largely German-made before the war, and the Graphite Company are able to claim that in capital management and manufacture their business is entirely British.

Pig Iron.—Messrs. Hall and Pickles, Limited, 64 Port-street, Manchester, send three catalogues dealing with pig-irons for which they are agents. Sheepbridge, made by the Sheepbridge Coal and Iron Company, Limited; and Thorncliffe and Special Cylinder made by Messrs. Newton, Chambers & Co., Limited. It is interesting to note that the cylinder pig-iron is all English ore, and that the high quality is obtained by using an old-fashioned blast furnace in which the blast is only slightly pre-heated.

WORLD'S SHAFT-SINKING RECORD.—In his paper upon the advantages of circular shafts, which was read a few months ago at a meeting of the South African Institution of Civil Engineers, Mr. H. Stuart Martin gave the following details with reference to a splendid piece of work at the No. 15 shaft, Crown Mines, during the month of December, 1918. Diameter, 21 ft. 6 in. (20 ft. in the clear): During 31 days, 279 ft. were sunk. Costs taken over 30 days (270 ft.) totalled 13*l.* 4*s.* 8*d.* per foot. These costs include the whole of the station cost—walling only excluded. The average tons hoisted per blast was 90, making 8,100 tons for 30 sinking days, three blast per day. Average of 31 natives per shift in shaft per day, or 93. White men in shaft: Leading hand sinker, 1 per shift, 3 per day; second hand sinker, 1 per shift, 3 per day; stagemen, 1 per day; master sinker, 1 per day. Total in shaft per day, 8. Total other whites employed on surface: Engine drivers, 3; boilermen, fitter blacksmith, machine men and masons workshops, &c., 9; grand total, 20. The total explosives used amounted to 15 lb. per foot sunk. Machines: Four Holman torpedo sinkers; two Holman jack hammers. A depth of 279 ft. sunk in 31 days constituted then the world's record for speed in sinking, covering all forms of shaft. This shaft-sinking record has again been broken at the same shaft, the footage accomplished for the month of July, viz., 31 days, being 310 ft. The total tonnage of rock hoisted for the 31 days amounted to 10,134 tons. This work was carried out under the supervision of Mr. Ivor Rees. In this last instance also the rock drills used were the Holman sinker and Holman hand hammer.

POWDERED FUEL FOR PUDDLING FURNACES.

*Report on Experimental Use of Powdered Fuel for Puddling Furnaces.**

By W. SIMONS (Stoke-on-Trent).

BEFORE deciding to incur the large expenditure involved in adopting a powdered-fuel plant for the forge, it was arranged, in view of the many factors that enter into the question, to make an experiment at one of the puddling furnaces of the Shelton Iron, Steel and Coal Company, Limited, and a plant was ordered in this country for the purpose, the powdered fuel for the test being specially obtained from a crushing plant usually used for cement.

The fineness of the coal dust was all that could be desired, but owing to the dust having to be brought a considerable distance on the railway, a quantity of moisture was absorbed, and the powdered fuel therefore contained more than is desirable and more than would be obtained if a complete plant were put down at the forge. The moisture in the fuel used for the experiment varied from 1½ per cent. to 2½ per cent., but there would be no difficulty in getting it down to 1 per cent.

Heating Up.—No difficulty was experienced in getting the requisite temperature. The time taken for heating the furnace from cold did not take more than 1½ hours, as compared with 3 hours to 4 hours required for ordinary firing.

Wear in Brickwork.—With the first position in which the burner was fixed the flame caught the roof of the combustion chamber, causing rapid wear of the brickwork. The position of the burner was altered, and at present comparatively little wear is taking place, but there is no doubt that further improvements can be made in the combustion chamber and in the form of the furnace to adapt it to this system.

Fuel Consumption.—This works out at about 30 per cent. better than the usual consumption of fuel per ton of iron made. Further economies can be made with the experimental plant, and with the greater range of regulation that would be provided in a complete plant still further reductions in fuel consumption could undoubtedly be effected.

Waste Heat.—A meter was fixed to the feed-water pipe of the boiler and the evaporation of the boiler was reduced by 10 per cent. for 30 per cent. reduction in fuel, but with the increased output that could be obtained by the use of powdered fuel there should be no reduction in the total evaporation of the boiler previously obtained.

Output.—There is no doubt that greater output can be obtained with powdered fuel owing to the complete combustion of the fuel. The under hand is relieved of the work of firing and is set free to assist the first hand. Heats were worked in 1½ hours, and in one case 1 hour 20 minutes, and the furnace was held back to some extent by having to take its turn with other coal-fired furnaces.

General.—The result of the experiment leaves no doubt that there is a great advantage in using powdered fuel for firing puddling furnaces. Greater output can be obtained, and economy of at least 30 per cent. should be obtained in the fuel used.

The men who have worked the furnace appear to be pleased with the result, and are anxious to know whether it is intended to put down a complete plant.

On the basis of 30 per cent. fuel economy, and taking the cost of a plant for about ten puddling furnaces and firing two Lancashire boilers (which are adjacent to the forge) as being 22,000*l.*, and allowing 2*s.* 9*d.* per ton on fuel for grinding, but without allowing for interest and depreciation, there is a net saving per annum of 23 per cent. on the capital outlay.

In view of the importance of fuel economy, the result of this experiment may prove of interest.

AMERICAN BATTLESHIP CONSTRUCTION.—We read in *The American Marine Engineer* that the contract for the construction of battleship No. 53 was let recently by the Navy Department to the Newport News Ship-Building and Dry Dock Company. The contract price was not announced. The battleship probably will be named the Massachusetts or Iowa, and when completed, from present indications, will be the largest war vessel in the world.

A PENNSYLVANIA SCHOOLSHIP.—Governor Sproul, of Pennsylvania, on July 10, approved a Bill passed by the Legislature of that State providing for a State nautical schoolship under authority of the Commissioners of Navigation of the Delaware. This measure, says the *American Marine Engineer*, carries an appropriation of 100,000 dols, and provides for the reception by the Commissioners of such vessels as may be assigned by the Secretary of the Navy for this purpose.

AMERICAN BRASS CARTRIDGE CASES FOR SALE.—We read in *Engineering and Mining Journal*, New York, that a million and a-half brass cartridge cases are to be offered for sale at 20 per cent. above the current market price of their metal content. Aircraft manufacturers have advised the Director of Sales that there are many novelty and souvenir uses for these condemned shells. The offering includes artillery cases of the following sizes:—75 mm., weight 2·61 lb.; 4·7 in., weight 8·25 lb.; 6 in., weight 7·03 lb.; 3 in., anti-aircraft, weight 6·75 lb.

* Paper read before the Iron and Steel Institute, on Thursday, September 18, 1919.